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Major P. A MACMAHON, D.Sc., Sc.D., LL.D., F.R.S., PRESIDENT, in the Chair.

William Henry Allen, J.P., D.L., Bromham House, near Bedford, Vice-President of the Institution of Mechanical Engineers;

John Edensor Littlewood, F.R.S., Fellow and Lecturer, Trinity College, Cambridge;

William Evan M'Farlane, M.B., Ch.B., F.R.G.S., Surveyor to Walsh District Hospital, Medical Officer of Health, Irvinebank, North Queensland, Australia;

Lieut.-Commander Edvin Smith, M.A., R.N.V.R., Tillsenburg, Ontario, Canada;

Henry Hayden Waters, 16 York Avenue, Great Crosby, Liverpool; and

Major A. J. Wolff, D.S.O., R.E., Ordnance Survey Office, Southampton,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

William Wykeham Jacomb, Lieut. R.N., care of H. S. King & Co., 9 Pall Mall, S.W.1 (proposed by A. R. Hinks);

Rev. Walter A. Mátos, 309 College Avenue, Swarthmore, Pennsylvania, U.S.A. (proposed by Monroe B. Snyder);

Guy B. Petter, 7 Princes Street, Yeovil (proposed by the Rev. T. E. R. Phillips);

Vedaranyesvara Vaidyanatha Ramana Sastrin, Ph.D., F.Z.S., Vedaraniam, Tanjore Dt., South India (proposed by Rohani Thirunal);

Herbert William Thomson Roberts, Alpha, Castle Avenue, Broadstairs (proposed by O. T. Olsen);

William Edward Sparkes, 8 Claremont Terrace, Sunderland (proposed by T. W. Backhouse); and

Ernest O. Tancock, Wellington College, Berks (proposed by the Rev. T. E. R. Phillips).

Thirty-eight presents were announced as having been received since the last Meeting, including, amongst others:—

Photographs of the Total Solar Eclipse of 1918 June 8, taken by the Crocker Expedition of the Lick Observatory, presented by Professor Campbell.

The New Star of Hipparchus and the Dates of Birth and Accession of Mithridates. By J. K. Fotheringham, M.A., D.Litt.

In *The Observatory*, 41 (1918), pp. 303, 304, 367, Professor Turner referred to a study on the "new star" of Hipparchus which was suggested to me by the recent appearance of a new star in Aquila, but which was not ready for publication when he wrote.

The following is, to the best of my knowledge, a complete collection of ancient references to this star, and to the comet of B.C. 120, which two ancient authorities regarded as identical with the earlier star.

Pliny, *Natural History*, 2, 26 (24), 95:—

> The afore-mentioned Hipparchus, who has never been sufficiently praised, in that he has beyond all others established the kinship of the stars to man, and has shown that our souls are a part of heaven, detected yet another new star, begotten in his own age, and by its motion, where it shone, he was led to question whether this phenomenon did not happen with some frequency, and whether those stars also which we think fixed might not be in motion, and accordingly he ventured on a thing which even in a god would be presumptuous, to enumerate the stars for posterity and to mark out the heavenly bodies by name, devising instruments by which he could note the position and magnitude of each star, so that it could easily be discerned from his work not only whether they died and were born, but whether any of them travelled or moved at all, and in like manner whether they increased or diminished in size, the heavens being thus left as an inheritance to all, if anyone should be found competent to receive it.

Justin, *Epitome of the Philippic Histories of Pompeius Trogus*, 37, 2 :—

His [*i.e.* Mithridates'] future greatness was predicted also by celestial portents. For both in the year in which he was begotten and in that in which he first began to reign, the star Cometes shone for seventy days on each occasion with such lustre that the whole sky seemed to be on fire. For with its magnitude it had taken possession of a fourth part of the sky, and with its splendour it had overcome the brightness of the Sun, and in rising and setting it took up a space of four hours.

Julius Obsequens, *Book of Prodigies* (ed. Rossbach [1910], p. 159) :—

In the consulship of P. Africanus and C. Fulvius [B.C. 134] the Sun was seen at night at Amiternum, and his light was seen for some time.

Se-ma Ts'ien, *She Ke*, translated by E. Chavannes under the title of *Les Mémoires historiques de Se-ma Ts'ien*, 3 (1899), p. 392 :—

The Standard of Tch'e-yeou resembles a comet, but is curved backwards ; it has the figure of a standard ; when it appears the reigning prince subdues and punishes the four sides [of the world].

Ibid., p. 408 :—

In the years *yuen-koang* [B.C. 134–129] and *yuen-cheou* [B.C. 122–117] the Standard of Tch'e-yeou appeared twice ; its size was such that it filled half the sky ; thereafter the armies of the capital marched out four times ; the massacres of (the barbarians) I and Ti lasted several decades, and the attacks upon the (barbarian) Hou were still more violent.

The Book of the Early Han,* astronomical section :—

In the 1st year of the epoch Yuen Kwang, the 6th month, a strange star was seen in Stellar Division Fang. The astrologer said "It signifies war" ; in the 2nd year, the 11th month, the Shen Yü entered Wu Show (district) with 100,000 horse, and Han sent 300,000 to meet them.

Ibid., annals of the Emperor Wu :—

In the spring of the 3rd year of the epoch Yuen Show, there was a comet seen in the East.

It will be observed that of the authorities cited none but Julius Obsequens and *The Book of the Early Han* give exact years, which can readily be reduced to our era, and, while Justin's comet which overcame the brightness of the Sun may well be identical with Julius Obsequens' nocturnal sun, I should, apart from the identity of the date, have hesitated to identify the latter

* I owe these two extracts from *The Book of the Early Han* to Mr. Tung Fu. The first sentence of the earlier extract is cited by Edouard Biot in *Connaissance des Temps pour l'an* 1846 (1843), additions, p. 61, from the Encyclopædia of Ma-twan-lin, who doubtless derived it from *The Book of the Early Han*. John Williams, *Observations of Comets* (1871), p. 6, cites the first sentence of the earlier extract and the whole of the later from what he calls the "She Ke." *She Ke* (*i.e.* Historical Records) is the title of Se-ma Ts'ien's great historical and scientific treatise. Williams regarded the dynastic histories as a continuation of this work, and refers to them all under the title of *She Ke*. The two passages here cited are not in Se-ma Ts'ien's work, but, as seen in the text, are to be found in *The Book of the Early Han*.

prodigy with those recorded by the other writers. Chavannes has made a close study of the Chinese calendar during this period, and has found that the 6th month of the 1st year of the epoch Yuen Kwang lasted from June 23 to July 21 of the Julian calendar, 134 B.C. See his paper, "La Chronologie chinoise de l'an 238–87 av. J.C.," *T'oung Pao*, 7 (1896), p. 31. Biot* had previously equated this month with July, and Williams† had equated it with June. The spring of the 3rd year of the epoch Yuen Show should be the spring of 120 B.C.

Biot has found that most of the Chinese "strange stars" (Ke-sing) are comets without apparent tails, and it might be supposed that the phenomenon observed in 134 B.C. was of that character. It is rash to postulate visibility of an unknown comet's tail, but, so far as we can reconstruct the conditions, they are fairly consistent with the brilliant phenomenon described by Justin and Se-ma Ts'ien. As a comet's tail always points away from the sun, its maximum length as seen from the earth must be the arc contained between the comet's nucleus and the point opposite the sun; within that limit the tail may be of any length, great or small. Again, a comet's tail is more likely to be seen outside than within the limits of twilight, and to that extent again the visibility of the tail depends on the distance from the sun. The "strange star," we are told, was seen in Stellar Division Fang, the Chinese name for a part of the heavens including portions of our constellations Libra, Lupus, Ophiuchus, and Scorpio. It contains no star brighter than the third magnitude, the brightest being δ Scorpii, which is nearly in the centre of the division. I find that at the beginning of the sixth Chinese month in 134 B.C. δ Scorpii was 117°, and at the end of that month 99° distant from the sun, which stood in the constellation Gemini at the earlier of those dates and in Leo at the later. It would appear then that the comet, when seen in Stellar Division Fang, had passed its nearest approach to the earth and, if seen at the end of the month, may have had a tail of anything up to 80° in length. This amounts to considerably less than Se-ma Ts'ien's half or Justin's fourth of the sky, but their estimates were probably not based on actual measurement. I find also that during the month in question δ Scorpii and, therefore, the comet also, was well placed for observation after the end of twilight. The capital of the early Han was Chang-an in Shen-si. Assuming a latitude of 35° North for this province, and, taking from Schmidt's observations made at Athens in 38° North,‡ for the depression of the sun at the end of twilight, 15° 18′ at the beginning and 15° 31′ at the close of that month, I find that δ Scorpii was 40° above the horizon at the end of twilight at the earlier and 31° at the later date. I also find that at Mithridates' birthplace, Sinope, 42° 2′ North latitude, the interval between the setting of δ Scorpii and of the point opposite the sun was 4·1 hours at the beginning and

* *Ubi supra.* † *Ubi supra.*

‡ *Astronomische Nachrichten*, Band 63 (1864), 114.

6·8 hours at the end of the month, reckoning the interval between sunset and sunrise according to ancient Greek practice at twelve hours. From this it would seem to follow that, if the identification is correct, Justin's statement of the time taken by the comet to set is more modest than the estimates of the length of its tail. Of course a comet east of the sun would not be likely to be seen rising. And, if the comet was seen for seventy days, it could not have spent the whole time in Stellar Division Fang.

There are further reasons in support of this identification. *The Book of the Early Han* records the phenomenon in its astronomical section, and cites the interpretation by the astrologer, *i.e.* by the astrologer or astronomer royal, Se-ma T'an, father and predecessor of Se-ma Ts'ien. It will be observed that the historian connects it with a barbarian war. The passages cited above from Se-ma Ts'ien are from the astronomical section of his work; one of them records an appearance of the Standard of Tch'e-yeou in the epoch Yuen Kwang, and, although the year is not named, 134 B.C. is the only year in that epoch for which we have any record of the appearance of a comet or similar phenomenon; they connect the phenomenon with a barbarian war, and incidentally they explain the phrase "strange star" by explaining that the Standard of Tch'e-yeou "resembles a comet." Its curved tail seems to have prevented Se-ma T'an from describing it as a comet, and hence the author of *The Book of the Early Han* gives it the title of "strange star," which, as Biot found, usually indicates a comet without apparent tail. I have little doubt that both the notice in the *She Ke* and that in *The Book of the Early Han* go back ultimately to Se-ma T'an.

The general description of the comet as given by Se-ma Ts'ien agrees sufficiently with that given by Justin to make their identity highly probable. But the fact that the same comet is supposed by both writers to have returned at what is apparently the same interval, clinches the argument. The first appearance of the Standard of Tch'e-yeou cannot be identified with any dated comet except that of 134 B.C.; the second appearance, falling in the epoch Yuen Show, might be either the comet of the spring of 120 B.C. (nearly fourteen years later), or that appearing in the fourth Chinese month in 119 B.C.* (nearly fifteen years after the appearance in 134 B.C.). Now these dates agree closely with the best dates fixed on other grounds for the conception and accession of Mithridates, and the former interval agrees exactly with the interval between these two events as stated by Memnon. The fullest modern monograph on Mithridates is T. Reinach's *Mithridate Eupator, Roi de Pont* (1890). While treating the comets as legendary and ignoring them in his discussion of the chronology, he concludes on other grounds † that Mithridates was born in 132 B.C. and began to reign in 120 B.C. Neither of these dates is certain apart from the evidence provided by the comets, but there is only a margin of a few years in each case. In spite of

* Williams, *ubi supra.*

† See p. 51.

the abundance of Chinese observations of comets in the time of Se-ma T'an,* none is recorded between 134 B.C. and 120 B.C., and, unless these two brilliant comets belong to those years, we shall have to suppose that our two ancient authorities for the age of Mithridates at his accession, Strabo and Memnon, have both been guilty of an understatement. According to Strabo, 10, 4, 10 (ed. Meineke, 1877, p. 672), Mithridates was eleven years old, and according to Memnon, cap. xxxii., in Photius' *Bibliotheca*, cod. ccxxiv. (ed. Migne, *Patrologia Græca*, 103 [1860], 905D), he was thirteen years old, at his accession. The latter statement is consistent with the dates given by the cometary appearances, and we thus get 134 B.C. for the conception, and 133 B.C. for the birth, and confirm Reinach's date of 120 B.C. for the accession of Mithridates. But it must be remembered that the only reason for preferring 120 to 119 B.C for the second appearance of the Standard of Tch'e-yeou is that it agrees better with the literary evidence for the date of Mithridates' accession and his age at that event.†

Although the comet of 134 B.C. has been known to Western scholars since the appearance of Biot's paper in 1843, and although the comet of 120 B.C. has been known since the publication of Williams' *Observations of Comets* in 1871, modern writers have curiously failed to use this material for identifying the comets mentioned by Justin. Thus Eduard Meyer in his *Geschichte des Königreichs Pontos* (1879) ignores these comets altogether, while Reinach,‡ as has been seen, treats them as legendary. He writes:—

> La légende s'est formée de bonne heure autour des premières années de Mithridate Eupator. Des comètes d'une grandeur et d'un éclat inusités saluent sa naissance et son avènement, annoncent la durée de son règne, l'étendue de ses conquêtes.

In a footnote M. Reinach ventures to explain the recorded phenomena of these comets by the events which he thinks they were invented to predict. He was, of course, unaware that their length was also recorded by Se-ma Ts'ien. The footnote runs :—

> La comète brille pendant 70 jours (les 70 années que vivra Mithridate), occupe la quatrième partie du ciel (il sera le maître du quart du monde), éclipse l'éclat du soleil (de l'empire romain). Quant aux quatre heures qu'elle met à se lever et à se coucher, je n'en comprends pas bien le sens symbolique, à moins qu'il ne s'agisse de la durée des deux principales guerres mithridatiques (88–85, Sylla ; 66–63, Pompée).

The identification of comets by the ancients was of course governed by the similarity of their appearance, not by any com-

* Williams has collected Chinese observations of nine or ten comets during the thirty years in which Se-ma T'an was astronomer royal (140–110 B.C.).

† The best literary authorities for the length of Mithridates' reign are Appian (*Mithridates*, 112), according to whom he lived 68 or 69 years and reigned 57, and Pliny, *Nat. Hist.*, 25, 2 (3), 7, according to whom he reigned 56 years. As he died in 63 B.C., he should have begun to reign in 120 or 119 B.C.

‡ *Ubi supra.*

putation of their orbits, of which ancient astronomy was incapable. It was for this reason that the comets of 134 B.C. and 120 B.C. were identified both in China and in Asia Minor. Greek astronomy has preserved to us the names of several comets, identified by their appearance.* If then a comet of an unrecorded shape appeared, it might naturally be called either a "strange star" or a "new star." There can, I think, be little doubt that the Standard of Tch'e-yeou, appearing in 134 B.C., was identical with the new star observed by Hipparchus and begotten in his age, as recorded by Pliny. The record of the observation follows a series of cometary observations, and this alone renders it probable that the new star at least resembled a comet. The reference to its motion proves that it was a comet. The novelty of the star lay in its strange shape. Its appearance was important in the history of astronomy, because it suggested to Hipparchus the construction of his catalogue; and what we know of the date of that catalogue confirms the identity of Hipparchus' new star with the comet of 134 B.C. Though the exact date of the catalogue is not definitely stated, there is evidence from which we can infer it. Hipparchus, according to Ptolemy, determined the longitude of Spica from a number of lunar eclipses, two of which can be dated, 146 B.C. April 21 and 135 B.C. March 21.† The list of equinox observations closes in the 50th year of the 3rd Callippic cycle, 128 B.C. March 23.‡ Hipparchus is elsewhere cited by Ptolemy as having recorded from his own observations the longitude of Regulus in the 50th year of the 3rd Callippic cycle, 129–128 B.C.§ This citation probably refers to Hipparchus' catalogue place for that star, from which it would follow that 129–128 B.C. was the epoch of his catalogue. Ptolemy describes this observation as 265 years earlier than his own. The same interval is used by him in comparing Hipparchus' declinations with his own,‖ and the inference is that these observations also are regarded by him as belonging to that year. Altogether it would appear that that was the year in which Hipparchus finally determined the positions of the fixed stars. If so, the comet of 134 B.C. would be the most recent and, so far as our evidence goes, the most brilliant of all the new stars that could have been observed by Hipparchus before the construction of his catalogue. We need, therefore, have no hesitation in identifying it with the comet of Justin, the Standard of Tch'e-yeou, and the "strange star" of *The Book of the Early Han*, to which we may probably add the nocturnal sun of Julius Obsequens.

6 *Blackhall Road, Oxford:*
1919 *Jan.* 4.

* See the references in Bouché-Leclercq, *Astrologie Grecque* (1899), pp. 357–62, and particularly the list of comet-names in the footnote on p. 359.
† Ptolemy, *Math. Syn.*, 3, 1, ed. Heiberg, 1 (1898), p. 199.
‡ *Ibid.*, p. 196.
§ *Ibid.*, 7, 2, ed. Heiberg, 2 (1903), p. 15.
‖ *Ibid.*, 7, 3, p. 23.

Observations of Nova Aquilæ, 1918.

By the Rev. J. G. Hagen, S.J., Assoc. R.A.S.

Observations of Nova Aquilæ were made here with the naked eye only, and without any special effort to secure a complete record of the star's fluctuations. Regular work with the great refractor would not allow more than incidental attention to the new star. If these observations are now offered for publication, it is not so much for their intrinsic value as for the manner of reduction, which the writer's acquaintance with the entire literature on variable stars, from Sir Wm. Herschel to this day, has led him to consider as well sanctioned by practice. Though not the exclusive method, it has the claim of being the oldest, and for this reason, if for no other, it seems to deserve being known by observers of variable stars.

I. *The Comparison Stars.*

1. The magnitudes of the comparison stars are taken from the Harvard Revision (*Harv. Ann.*, **50**). From the means of the estimated intervals the column Grades was formed by simple addition. The Colours are those of Krüger and Osthoff, now being published by the Vatican Observatory as No. ix. "Index Catalogue" (not yet distributed).

TABLE I.—*Comparison Stars.*

Star.	Desig.	H.R.	Grades.	Colour.	Formula.	Curve.
		m	G.	C.	m	m
α Lyræ	L	0·14	0·0	1·3	0·53	0·25
α Aquilæ	A	0·89	7·0	2·4	1·12	0·90
α Cygni	C	1·33	11·3	2·1	1·36	1·25
α Ophiuchi	O	2·14	18·8	2·5	1·89	1·85
ζ Aquilæ	ζ	3·02	28·8	2·7	2·56	2·65
δ Aquilæ	δ	3·44	35·8	3·9	3·16	3·15
β Aquilæ	β	3·90	42·1	5·1	3·71	3·60
θ Serpentis	θ	4·10	48·6	3·0	3·87	4·05
α Scuti	α	4·06	51·3	6·1	4·43	4·20
ι Aquilæ	ι	4·28	55·0	3·1	4·30	4·45
ν Aquilæ	ν	4·86	63·1	4·4	4·98	4·90
4 Fl. Aquilæ	F	5·04	71·3	2·5	5·28	5·20

2. A comparison between the columns H.R. and Grades shows that it would not be correct to reduce the observations by the Harvard magnitudes as they stand. For the star α Scuti there is an inversion of order, easily explained by the deep colour of the star. In the telescope it appears brighter, relative to other stars, than to the naked eye, and this must be so in accordance with the "Purkinje Phenomenon." Hence, applying directly the Harvard magnitude 4·06, which is a telescopic measure, to a naked-eye observation would come to the same as reducing the observation with a wrong star.

3. It follows that magnitudes are to be computed which, while based on the H.R. system, will fit into the scale of grades. A linear formula may be sufficient for the present purpose, although a quadratic one, containing the squares of the grades, would yield better results. If we put

$$\text{H.R.} = x + y\ \text{Grade} + z\ \text{Colour},$$

we have twelve equations of condition. Giving all of them equal weight, we obtain the formula

$$\text{Mag.} = 0^{\cdot}37 + 0^{\cdot}064\ \text{Grade} + 0^{\cdot}12\ \text{Colour},$$

from which the column Formula was computed.

The coefficient $0^{m}{\cdot}064$ is the observer's value of one grade or step for the naked eye. In a 5-inch refractor (at Georgetown University) it used to be, on an average, $0^{m}{\cdot}054$ (see *Ast. Jour.*, **10**, 177, and **11**, 172), and in the 12-inch telescope $0^{m}{\cdot}037$ (see *Publ. Specola Vaticana*, **11**, "Aggiunte," p. 26).

The positive sign of the colour-coefficient is in agreement with the general experience that deeply coloured stars become brighter, relative to white stars, when viewed with stronger optical means. To the naked eye they must appear fainter.

4. The grades are supposed, and are surely intended by every observer, to be uniform over the entire scale. The same must hold for the magnitudes, whether computed from a linear or from a parabolic formula. The uniformity should show itself graphically in the shape of a smooth curve, and any deviations from the curve must be considered as errors of observation. To eliminate these errors, the computed magnitudes were plotted as ordinates over the grades as abscissæ. The resulting curve was not a straight line, which proves that a quadratic formula would have been preferable. Table II. may serve as a definition of the magnitude-curve.

TABLE II.—*Magnitude Curve.*

Grade. G.	Curve. m	Grade.	Curve. m
0	0·25	40	3·45
5	0·70	45	3·80
10	1·15	50	4·15
15	1·55	55	4·40
20	2·00	60	4·70
25	2·35	65	4·95
30	2·70	70	5·20
35	3·10	75	5·40

II. *The Observations.*

The dates are counted from Greenwich mean noon. During the first two months the times might have been noted more exactly. The letter N designates the Nova, and the comparison star on its left is always the brighter of the two.

The columns headed I. and II. were computed from the formulæ

$$(\text{I.})\ \mathrm{R} = \tfrac{1}{2}(a+b) + \tfrac{1}{2}(m-n),$$
$$(\text{II.})\ \mathrm{R} = a + m(b-a)/(m+n) = b - n(b-a)/(m+n),$$

where the observation is supposed to be written thus: *am*R*nb*, the letters *m* and *n* denoting the estimated steps and R the variable.

The first formula corrects errors committed in the apprehension of the stellar brightness, the second reduces the actual step value to its mean value. Thus the next column, headed Mean, gives the best figures that can be drawn from the observations. The last column, Mag., was read from the magnitude curve.

TABLE III.—*The Observations.*

Date.	h	Observ.	I.	II.	Mean.	Mag.
June 13	8	L5N2A	5·0	5·0	5·0	0·7
15	10¼	C1N6O	12·6	12·4	12·5	1·4
20	13	A1oN2O	16·9	16·8	16·9	1·7
21	11	O3N6ζ	22·3	22·1	22·2	2·1
22	10	O6N5ζ	24·3	24·3	24·3	2·3
24	11	ζ2N6δ	30·3	30·5	30·4	2·8
25	9	ζ3N7δ	30·3	30·9	30·6	2·8
27	9½	δ7N2β	41·4	40·7	41·1	3·6
29	9	δ1N5β	37·0	36·9	36·9	3·3
30	9	δ2N6β	37·0	37·4	37·2	3·3
July 2	8–9	δ1N7β	36·0	36·6	36·3	3·2
3	8–9	ζ4N3δ	32·8	32·8	32·8	3·0
5	8–9	ζ5N2δ	33·8	33·8	33·8	3·0
7	8¾	δ1N7β	36·0	36·6	36·3	3·2
8	8½	δ1N6β	36·4	36·7	36·6	3·2
13	8½	δ3N5β	38·0	38·2	38·1	3·3
14	8¾	δ4N2β	40·0	40·0	40·0	3·5
15	9	β3N6θ	43·8	44·2	44·0	3·8
16	11·0	β3N5θ	44·3	44·5	44·4	3·8
17	9½	β2N6θ	43·3	43·7	43·5	3·7
25	8½	β3N3θ	45·4	45·4	45·4	3·9
26	8½	β3N3θ	45·4	45·4	45·4	3·9
27	8	β3N4θ	44·8	44·9	44·9	3·8
28	10	β3N5θ	44·3	44·5	44·4	3·8
30	8	β3N4θ	44·8	44·9	44·9	3·8
31	8½	β5N2θ	46·9	46·8	46·9	4·0
Aug. 2	8·0	α3N5ι	52·1	52·7	52·4	4·3
4	10·0	θ4N1ι	53·3	53·7	53·5	4·5
5	8·3	ι4N3ν	59·6	59·7	59·6	4·7
6	9·5	ι2N6ν	57·0	57·0	57·0	4·6
7	8·1	β2N4θ	44·3	44·2	44·3	3·8
8	7·9	β3N3θ	45·4	45·4	45·4	3·9
8	7·9	β3N3				

Date.	h	Observ.	I.	II.	Mean.	Mag.
Aug. 9	8·0	β2N4θ	44·3	44·2	44·3	3·8
11	8·0	β3N3θ	45·4	45·4	45·4	3·9
12	8·1	θ1N4ι	50·3	49·9	50·1	4·2
13	8·9	ι2N6ν	57·0	57·0	57·0	4·6
14	9·5	ι3N6ν	57·5	57·7	57·6	4·6
15	8·7	ι4N6ν	58·0	58·2	58·1	4·6
24	7·9	ι6N3ν	60·6	60·4	60·5	4·8
26	8·3	ι4N5ν	58·5	58·6	58·6	4·7
27	9·8	θ1N4ι	50·3	49·9	50·1	4·2
28	8·2	β3N2θ	45·9	46·0	45·9	3·9
30	13·0	β1N4θ	43·8	43·4	43·6	3·7
31	7·4	ι4N2ν	60·1	60·4	60·2	4·7
Sept. 1	7·9	Noν	63·1	...	63·1	4·9
3	7·2	ι5N3ν	60·1	60·1	60·1	4·7
4	7·9	ι5N4ν	59·6	59·5	59·5	4·7
5	7·0	ι5N3ν	60·1	60·1	60·1	4·7
6	7·1	ι4N4ν	59·1	59·1	59·1	4·7
7	7·4	ι2N4ν	58·0	57·7	57·9	4·6
9	8·8	ι3N5ν	58·0	58·9	58·0	4·6
10	9·5	ι4N4ν	59·1	59·1	59·1	4·7
11	8·2	ν1N7F	64·2	64·1	64·2	5·0
12	9·1	ν2N5F	65·7	65·4	65·6	5·0
29	7·5	ν3N6F	65·7	65·8	65·8	5·0
30	8·0	ν3N5F	66·2	66·1	66·2	5·0
Oct. 3	7·5	ν3N6F	65·7	65·8	65·8	5·0
7	8·0	ν2N6F	65·2	65·1	65·2	5·0
22	6·0	F1N	72·3	...	72·3	(5·3
26	6·2	F3N	74·3	...	74·3	(5·4
27	6·4	F4N	75·3	...	75·3	(5·4
Nov. 5	6·0	F4½N	75·8	...	75·8	(5·4

III. *The Light-curve.*

This curve may be plotted from either grades or magnitudes, as ordinates. When there is question of recognising undulations in the curve, grades lead to better results, because the magnitudes diminish the range of these phases. Once the times of the secondary max. and min. are determined, the magnitudes are readily applied.

The curve drawn for Nova Aquilæ, as far as it is continuous, shows two min. and three max., which are:

Minima: June 27 ($3^m{\cdot}6$) and August 5 ($4^m{\cdot}7$),
Maxima: July 3 ($3^m{\cdot}0$), August 7 ($3^m{\cdot}8$), and August 30 ($3^m{\cdot}7$).

There are breaks in the curve during the latter halves of July, August, and September, where other fluctuations may have occurred.

The colour of the Nova could not be estimated with any degree of certainty without a telescope. Only a few times a 4-inch refractor was used for the purpose, and the results were:

June 22 (7^c), 25 (8^c), 27 (8^c), 29 (8^c), July 16 (7^c), 25 (7^c),

expressed in the numerical scale: 0 = white, 3 = yellow, 6 = orange, 9 = red.

The writer wishes to insist that the above results are strictly comparable with other observations reduced to the Harvard system of magnitudes. Although new magnitudes were calculated to fit into the observer's grades, the scale remains that of the Harvard Photometry.

Vatican Observatory:
1918 *Dec.* 27.

The Spectrum of Nova Aquilæ, 1918 *June* 15.

By the Rev. A. L. Cortie, S.J.

The spectrum of Nova Aquilæ, 1918, on June 15 was a composite spectrum, marking a transition stage, between a spectrum full of dark lines, and one composed mainly of bright bands. Most of the fainter dark lines of the spectrum of June 10, identified as enhanced lines appearing in the spectrum of α Cygni, had disappeared. But the dark lines of hydrogen were still intense, the K line was pronounced, though much reduced in intensity, and the H line of calcium had seemingly disappeared, leaving H_ϵ in its place. Some of the dark lines of the earlier spectrum were still strong, particularly in the ultra-violet part of the spectrum.

Among such were the following lines, mainly spark or enhanced lines:—

3782		3901	
3815	Ti	3905	Cr
3850	Ni	3919	
3866	Cr	3934 K	Ca

These lines, which also appear in the spectrum of α Cygni, were all displaced towards the more refrangible end of the spectrum by some 20 A units. This indicates that they belonged to the dark-line spectrum corresponding to the first, or less displaced, of the three sets of dark hydrogen lines. For the hydrogen lines were triples, consisting in each case of a strong line followed, in order of refrangibility, by a more diffuse line, and a fainter line. Taking as the fiducial point the centre of the bright H_γ band, just at the less refrangible side of the central bright maximum, the following values of the line-of-sight displacements of the successive lines were obtained, the mean values of which are in good agreement with the values already published by other observers.

TABLE I.

Line-of-sight Velocities of the Hydrogen Lines. Nova Aquilæ, 1918 *June* 15.

	Set I.				Set II.			Set III.		
	Wave-lengths.									
	Normal.	Displaced.	dλ.	km./sec.	Displaced W.-L.	dλ.	km./sec.	Displaced W.-L.	dλ.	km./sec.
H_β	4862	4830	32	1817	4821	41	2529	4817	45	2778
H_γ	4341	4315	26	1796	4307	34	2348	4302	39	2695
H_δ	4102	4078	24	1754	4069	33	2407	4064	38	2779
H_ϵ	3970	3947	23	1738	3938	32	2412	3933	37	2796
H_ζ	3889	3866	23	1773	3858	31	2446	3854	35	2700
H_η	3836	3814	22	1720	3805	31	2424	3801	35	2744
H_θ	3798	3776	22	1738	3768	30	2370	3766	32	2527
H_ι	3771	3749	22	1750	3741	30	2386	3737	34	2705
	Means			1761			2415			2716

The components of $H\beta$ and H_γ were more difficult to measure, as they were lineally much closer than in the other hydrogen lines.

The bright-line spectrum consisted of a series of bright bands, marked, in several cases, by bright maxima. It could be traced in the ultra-violet as far as λ 3620. These bands were in many cases doubles, as for instance that at λ 4640. The structure of the bright hydrogen bands, especially H_γ, H_δ, H_ϵ, consisted of three subsidiary bright bands, the middle band being the broadest and brightest. The extreme widths of the bands were H_ϵ 40, H_δ 42, H_γ 50, and H_β 59 Angstrom units. A normal spectrum fits the middle of the bright bands. This position of the hydrogen lines in a normal spectrum also gives the values of the displacements of the three sets of dark hydrogen lines, which correspond closely, as we have seen, with those which have been derived by other observers, from slit-spectra, using a comparison spectrum.

This then would appear to be the proper positions of the fiducial points for determining wave-lengths, and it has been adopted in the following table. In a former paper * on the earlier spectrum of this Nova, the fiducial points for determining the

* *Monthly Notices*, 79, 121.

positions of the lines in the dark-line spectrum were placed at the more refrangible edges of the bright hydrogen bands. The wave-lengths were thus freed from the effect of the displacements which affected all the dark lines of the spectrum. But the values of the mean wave-lengths of the bright bands, given in the present paper, are probably more correct than those given in the former paper.

There seems to be no doubt that the positions of the dark hydrogen lines in a normal spectrum, such, for instance, as that of α Cygni, would occupy the middle positions of the broad bright hydrogen bands in the spectrum of the Nova. Observers heretofore have not unfrequently given displacement values for the bright bands of the hydrogen series, as well as for the dark lines, the former being supposed to represent a motion of recession in the line of sight. But this supposition is questionable. For the breadth of the bright hydrogen lines does not seem to represent a displacement, but rather a very great symmetrical widening on both sides of the central hydrogen line. This would be indicative of a correspondingly enormous pressure. The displaced dark lines, in all novæ representing a very high velocity of approach, would be likely to occur as the effects of an explosion, which was associated with a corresponding compression of the gaseous mass.

Again, many of the bright bands of the later stages in the spectrum of a nova, and many too of the bright enhanced metallic lines of the earlier stages, form a compound spectrum which seems to persist throughout the whole life-history of the display.* In other words, the stages in the transition of the spectrum, from that of an enhanced metallic-line spectrum to that of the bright-band spectrum of a nebula, are not sharply marked or separated. The bright band at λ 4640 is obviously an important member of this persistent spectrum. This would seem to indicate a possible explanation of the appearance of a new star as due to an explosion in a star which was already situated in a nebula, probably a dark nebula originally, which itself was put into luminous vibration by the explosion which took place in its midst. Perhaps its own gradual contraction on the star was the originating cause of the explosion. Photographs have abundantly proved the existence of such dark nebulæ in the Milky Way, and, in the case of Nova Persei 1901, the surrounding nebula was revealed telescopically, as well as spectroscopically.

In the following table the first column of wave-lengths gives the actual measures of the bright edges, and of the brighter maxima, in the bands. Each measure is the mean of at least three settings. The mean wave-lengths of the centres of the bands are given in the second column. These are compared, in the third and fourth columns, with those values of the wave-lengths of the bright bands in Nova Persei 1901,† and Nova Aurigæ 1892,‡ as published by Father Sidgreaves. The wave-

* *Monthly Notices, R.A.S.*, **73**, 652.
† *Ibid.*, **62**, 153 *et seq.*
‡ *Memoirs, R.A.S.*, **51**, 36 *et seq.*

lengths in the first two columns were computed from the measures by means of a curve of wave-lengths and micrometer readings, and by the Henroteau graphical method of the Hartmann-Cornu formula. The fifth and sixth columns contain the wave-lengths of dark lines in the spectrum of α Cygni, and the probable origins of such lines, taken from the South Kensington results.* The last column is devoted to remarks.

TABLE II.

The Bright Lines and Bands in the Spectrum of Nova Aurigæ, 1918 *June* 15.

Wave-lengths.	Intensity.	Mean Wave-lengths.	Nova Persei. (Stonyhurst.)	Nova Aurigæ.	α Cygni. (S. Kensington.)	Probable Origin.	Remarks.
3719							Nebular lines 3726,29.
28	1	3724					
33							
38	1	3736					
54					3751	H	3751 H_κ.
60	1	3757			3759	Ti	
67							
68	1	3768	3764		3771	H	3771 H_ι.
80					3782		
90	1	3785					
94							
3803	1	3799			3798	H	3798 $H\theta$.
12					3815	Ti	
26	1	3819					
33							
42	1	3838			3836	H	Nebular line 3836. H_η.
48					3850	Ni	
54	2	3851			3854	Si	
69							
76	2	3873			3873	Fe	Nebular line 3869.
84					3884		Nebular line 3889. $H\zeta$.
89	2	3889					
94					3896		
99					3898		
3909	2	3904			3906	Cr	
16							
31	2	3924			3923	Fe	
36	8	3936			3936		3934 K.

* "On some of the Phenomena of New Stars," Solar Physics Committee, 1914.

TABLE II.—*continued.*

Wave-lengths.	Intensity.	Mean Wave-lengths.	Nova Persei. (Stonyhurst.)	Nova Aurigæ.	α Cygni. (S. Kensington.)	Probable Origin.	Remarks.
3949	8	3953			3952	V	Bright line between H_{ϵ_1} and H_{ϵ_2}.
56							
64	8	3970		3974	3974	H	Three bright narrow bands in H_ϵ. Nebular lines 3965, 3968, 3970.
75							
81	8	3985			3982		Bright maxima in a band.
89							
96	2						
4003	1						
07	2	4015					
20	2				4016	Ni	
34	2		4032		4033	Mn	Nebular line 4027.
39	3						Bright edge.
48	4	4048			4049	Fe	Strong bright line.
60	3						Bright edge.
72	5	4070					Sharp bright line, double. Nebular line 4069.
4080	8						Three bright bands in H_δ.
85							
95	8			4095*d*			
4104		4102		4105	4102	H	
4115	8						
4122							
32	1	4135	4130		4131	Si	
37	2			4138			
58	2						
4214	2	4221					A double bright band.
28	3						
34	2	4244	4234	4234	4233	Fe	
53				4248	4247	Sc	
61	2	4268			4262	Cr	A double bright band.
75				4274			
83	2	4292					
4302			4303	4301	4303	Fe	
18	9			4316	4317	Ti	A bright line.
31	10						H_γ bright band.
41	10	4341		4346	4341	H	
55	10						Double bright lines.
68	9		4364	4366			Broad bright line.

TABLE II.—*continued.*

Wave-lengths.	Intensity.	Mean Wave-lengths.	Nova Persei. (Stonyhurst.)	Nova Aurigæ. (S. Kensington.)	α Cygni.	Probable Origin.	Remarks.
4378	2	4383	4384	4382	4388	He	Bright edge.
88							Companion band to H_γ.
4402	2			4396			
17	1			4419			
31	2	4437		4447	4444	Ti	
43							
59	2	4463	4471	4472	4472	He	
68							
4505	3	4511	4520	4502			Double bright bands.
17				4519	4520	Fe	
27	4	4537		4531			
46				4553	4550	Fe	
62	3	4573	4572	4568			4564. Campbell.
83							
89	2	4595		4585	4584	Fe	
4601							
12	4	4620		4629	4630	Fe	4628. Nova Persei. S. Ken.
27							
37	3	4645	4640				
52			4650				
4827	9						H_β band.
51	10	4862			4862	H	Broad bright double line.
62							
76	10						Bright line.
86	9						Bright edge.
4896	3	4922		4920	4924	Fe	Brighter lines in bright band.
4920							
4929							
4944							
73	2	5012		5014	5019	Fe	4779 } bright edges.
5020							5044 }
38							
61	1	5086		5085*d*			
5107							

In the plate illustrating the paper on the earlier spectrum of the Nova, *Monthly Notices*, **79**, 121, will be found an enlarged print of the spectrum of the star on 1918 June 15.

Stonyhurst College Observatory:
1919 *Jan.* 3.

The Pulsations of a Gaseous Star and the Problem of the Cepheid Variables. Part II.* By A. S. Eddington, M.A., F.R.S., Plumian Professor.

12. *Dissipation of Energy.*—We shall now examine the rate at which the oscillations of a gaseous star decay owing to thermal dissipation. When a portion of a gas is compressed, the temperature is raised, and heat tends to leak away; consequently the pressure falls, and the whole work of the compression is not recovered in the rebound. There will be other sources of dissipation, such as viscosity; but this leakage of heat seems at first sight the most threatening, and when the pulsatory theory was first suggested I found it difficult to conceive that the pulsation could last for more than a few periods. The discovery of the very high opacity within a star, however, gives a different aspect to the problem; the leakage of heat is very much smaller than would occur if we were dealing with low-temperature radiation for which gases are comparatively transparent.

If dQ is the heat gained from outside by an element of the star, and dW the work done by external pressures, then, for a complete cycle in which the element is restored to its original state,

$$\int(dW + dQ) = 0.$$

By the second law of thermodynamics dQ/T is a perfect differential so that

$$\int \frac{dQ}{T} = 0 \quad . \quad . \quad . \quad . \quad (34)$$

This assumes that the element acts as a reversible engine; that is to say, we neglect any dissipation within the element, and calculate only the dissipation due to the leakage of heat between different parts of the star.

Now

$$\frac{dQ}{T} = \frac{dQ}{T_0(1+T_1)} = \frac{dQ}{T_0} - \frac{T_1 dQ}{T_0}$$

approximately.

Hence by (34)

$$\int dQ = \int T_1 dQ$$

and therefore

$$\int dW = -\int T_1 dQ \quad . \quad . \quad . \quad . \quad (35)$$

a form which has the advantage that we need only calculate dQ to the first order in order to obtain the dissipation of mechanical energy dW which is a quantity of the second order.

Using the value of dQ/dt in (33), we obtain the rate of dissipation in any part of the star. For the whole star this must be integrated by quadratures. I take the solution for $\gamma = \frac{1.0}{.7}$, $\omega^2 = .06$

* For Part I., see p. 2.

in Table IV., which corresponds fairly closely to a typical Cepheid. The solution is available up to $\xi_0 = 5$, and the results below refer to dissipation within this sphere, which contains 99 per cent. of the mass.

The dissipation in ergs per second is found to be

$$8\pi c(1-\beta)\frac{n^2}{k}\left(\frac{R}{6{\cdot}9}\right)^3 \cdot \frac{3}{10} \cdot 714[\xi_1^2]_c$$

where the factor 714 comes from the numerical integration and $[\xi_1]_c$ refers to the amplitude of ξ_1 at the centre.

The kinetic energy of the pulsation at maximum is

$$\tfrac{1}{2}n^2\int(\xi_0\xi_1)^2 dM$$
$$= \tfrac{1}{2}n^2\frac{M}{2{\cdot}015}\left(\frac{R}{6{\cdot}9}\right)^2 \cdot 16{\cdot}8 \cdot [\xi_1^2]_c$$

where the factor 16·8 is found by numerical integration.

From Table IV. it appears that ξ_1 at the boundary is about 1·8 times its value at the centre, so that

$$[\xi_1]_c = \frac{5}{9}\frac{\delta R}{R}.$$

Applying these formulæ to δ Cephei, I find:

Dissipation of energy of pulsation $= 4{\cdot}7 \cdot 10^{41}$ ergs per year,
Total mechanical energy of pulsation $= 7{\cdot}5 \cdot 10^{44}$ ergs.

For comparison, I add the results from § 10:

Total radiation of energy $= 1{\cdot}0 \cdot 10^{44}$ ergs per year,
Exhaustion of potential energy $= 3{\cdot}7 \cdot 10^{48}$ ergs.

According to these results, the energy of pulsation of δ Cephei would last 1500 years at the present rate of dissipation, so that the variation might remain for some centuries without conspicuous change.

Comparing the whole energy of the pulsation with the negative potential energy, we see that a comparatively small change in the equilibrium distribution of mass would, if it could occur suddenly, start a pulsation with the necessary energy.

The dissipated energy of pulsation forms only 1/200 of the outflow of heat from the star.

It may be questioned whether a duration of the variation for a period of the order 1000 years is sufficient. It depends on our view as to the rate of stellar evolution. Shapley has found that in certain clusters the majority of the stars within certain limits of brightness are Cepheids, so that we should expect the variation to last for a time which is at any rate not insignificant with respect to evolutionary change. The cluster variables are, however, dense stars, and our calculations do not strictly apply to them.

It should be understood that we have calculated the dissipation due to one particular cause, and we have not considered possible counterbalancing causes, such as work done by radiation-pressure. The calculation is not intended as a determination of the actual life of the variation; it deals merely with one formidable objection to the pulsatory theory, and shows that the objection is less serious than it appeared at first sight.

13. *Conditions for Cepheid Variation.*—The uniform relations between the period, luminosity, and spectral type, which have been found by observation, show that the variation only occurs during a strictly limited stage in the development of a star. This seems to rule out the suggestion that it is provoked by some external accident such as a collision. Two possible explanations suggest themselves—

(1) During a certain stage the conditions are such that an oscillation having the appropriate period would tend to increase; thus the pulsation would start automatically.

(2) At a certain stage there is a sudden change in the state of stable equilibrium, and the collapse to the new state throws the star into a pulsation, which, according to § 11, could last for a period of the order 1000 years.

In either case it seems likely that every star of sufficient mass will become a Cepheid for a brief part of its life; this conclusion is, however, not inevitable, since the speed of rotation, for example, may make a difference in the behaviour of otherwise similar bodies.

I do not think that the first explanation contradicts any thermodynamical principles, but it does not obtain much encouragement from our analytical investigation. By (35) mechanical energy is gained or dissipated according as $T_1 dQ$ is positive or negative.

Now we have found (33) that

$$\frac{dQ}{dt} = \frac{4c(1-\beta)}{k\gamma}\left\{-n^2 T_1 + \frac{3\gamma-4}{\xi_0^2}\frac{d}{d\xi_0}(M\xi_1)\right\}$$

where M (the interior mass in gravitational units) is written for $g_0\xi_0^2$. The first term when multiplied by T_1 is necessarily negative, and therefore always gives dissipation. So long as ξ_1 and $d\xi_1/d\xi_0$ have the same sign, their sign is opposite to that of T_1 (by (11)) and the second term also gives dissipation. $d\xi_1/d\xi_0$ cannot change sign till near a node, *i.e.* near the boundary. The region where gain of mechanical energy is possible is thus very limited. It is difficult to say whether any gain actually does occur, because our adiabatic approximation is not valid in this outer region; but in any case it can scarcely compensate for the great loss in the interior regions.

In an earlier survey of this problem * I pointed out that the observed phase of the flow of heat is such that the dissipation of energy nearly vanishes, and radiation-pressure tends to maintain the pulsation. This appeared favourable to the hypothesis that

* *The Observatory*, 40, 290.

the pulsation is maintained automatically. But the detailed investigation now given shows that this phase-relation can only apply to the outer layers of the star; in the adiabatic interior H, ξ and T have been found to have the same (or opposite) phase, so that the superficial appearance is misleading.

According to either explanation the pulsation occurs at some critical state of the star. In the approximate theory of stellar equilibrium we assume that the giant stars differ from one another only in scale, so that the solution for one star is obtained from that of another by multiplying ξ, ρ, T, etc., by suitable constants. So long as the physical properties of the material—opacity, specific heat, molecular weight, etc.—are uniform throughout the star, we can find no reason for the discontinuity of condition between Cepheids and non-variable stars. We must therefore take into account a variation of these properties with temperature, or possibly with density. For example, it is not unlikely that the specific heat may change with temperature, being abnormally high for temperatures at which ionisation occurs rapidly.

It suggests itself that the condition for Cepheid variation may be a particular distribution of internal temperature; but, if our calculations in Table II. are correct, this cannot be strictly true. The central temperature seems to vary fairly systematically with the mass to an extent by no means negligible from the present point of view.

According to the theory of radiative equilibrium, this non-correspondence of temperature-distribution can be proved more precisely. From *Monthly Notices*, **77**, 600, equations (42), (43), (44), we have

$$T_e^4 \propto g(1-\beta) \propto M^{\frac{1}{2}}\rho^{\frac{1}{2}}(1-\beta)$$

$$T_c \propto \rho^{\frac{1}{3}}M^{\frac{2}{3}}\beta$$

$$1-\beta \propto M^2\beta^4.$$

Whence, eliminating M and ρ,

$$T_e \propto T_c\,(1-\beta)^{\frac{1}{8}}.$$

Thus if the central temperature T_c were the same for all Cepheids, we should have the effective temperature varying as the eighth root of $(1-\beta)$, and accordingly increasing slowly with the absolute luminosity. Observation, however, shows that the change is in the other direction, the type becoming redder as the luminosity increases.

If, however, the critical condition determining the variation occurs near the boundary, the case is somewhat altered. Owing to the smaller absorption of low-temperature radiation, radiation-pressure must become very small near the boundary. The result is that the temperatures in the outer layers depend on T_c/β instead of on T_c. From Table II. it appears that T_c/β is fairly constant for the Cepheids, the variations being apparently accidental. This

can be seen better by taking the two theoretical stars of § 11. We have

Period 4·5 days; $T_c = 3{,}750{,}000°$; $T_c/\beta = 5{,}830{,}000°$.
Period 30·8 days; $T_c = 1{,}970{,}000°$; $T_c/\beta = 5{,}810{,}000°$.

This suggests that the occurrence of variation depends on the conditions in the outer layers.

14. *Relation of Velocity and Luminosity.*—Up to the point in the star where the adiabatic approximation ceases to hold, the maximum outward flow of heat occurs at the moment of greatest compression (equation (31)). It is well known that the maximum outflow of heat from the surface occurs a quarter-period later, when the star is expanding most rapidly. The quarter-period retardation must occur in the intervening non-adiabatic region, but I have not succeeded in treating analytically the complicated equations relating to this part of the star.

It is easy to see that there must be some retardation in a region where the temperature oscillations are determined by the heat received and radiated rather than by compression and rarefaction. The heat flowing into this region is greatest at the time of compression; if the temperature remained constant, the heat leaving the surface would be greatest at the time of expansion (when the surface was greatest); from these two causes the heat contained would be greatest a quarter-period after compression. This heat, however, causes a rise of temperature, so that the time of maximum radiation becomes earlier; this advance reacts on the time of maximum temperature, bringing it also earlier; and so on. Apparently the net result is that the time of maximum radiation is advanced to a quarter-period after compression, with the time of maximum temperature about half-way between; but I have not been able to follow this out quantitatively.

Any general explanation without mathematical analysis must necessarily be somewhat uncertain, because the differential equations concerned are strictly of the fourth order, and the relations are therefore too intricate to be expressed in general terms. It is possible that at the boundary the equations will reduce approximately to the second order (as we have seen they do at the centre). The exact nature of this simplification ought to be established by mathematical analysis; in default of this, we may perhaps assume as guiding principle that the conditions at the boundary will go to the opposite extreme from those prevailing at the centre. In that case the explanation of the agreement between the velocity-curve and luminosity-curve seems to be as follows:—

If we consider spheres of radii ξ_1 and ξ_2 dilating with the material of the star, the effective opacity between them diminishes as the star expands, partly owing to the increase in radiating surface, and partly owing to the obstruction being thinned out to cover the larger surface. If the temperatures were unchanged, more heat would be let through. But the extra leakage of heat involves cooling, so that the excess flow of heat depends not on the actual

opacity at the moment, but on the lag of the temperature behind the opacity-change. This will be a maximum when the opacity is changing most rapidly. Consequently, the greatest flow of heat occurs when the opacity is diminishing most rapidly, *i.e.* when the velocity of expansion is greatest. This agrees with the observed result.

This, of course, does not apply to the interior, where the adiabatic expansion causes a drop of temperature, which more than counterbalances the effect of the increased transparency. But we suppose that at the boundary there is a layer where the adiabatic change of temperature is comparatively negligible, *i.e.* the material merely oscillates without compression, as at the open end of an organ-pipe.* It is true that immediately behind this layer the transparency is also increased, so that the expansion causes an increased inflow of heat as well as an increased outflow; but if we follow this back a little way we come to the part where the adiabatic conditions prevail and the inflow is actually diminished by expansion. Consequently in each intermediate layer the expansion of the star affects the outflow rather more strongly than the inflow, since the outer surface is more removed from the adiabatic condition than the inner surface, and the general result is as stated above.

It should be noticed that the time of maximum temperature is not the same as the time of maximum radiation. By (29) H is proportional to $\xi^4 d\mathrm{T}^4/d\xi_0$, so that

$$\frac{\delta \mathrm{H}}{\mathrm{H}_0} = \frac{4\delta\xi}{\xi_0} + \frac{4d(\mathrm{T}_0{}^4\mathrm{T}_1)}{d\xi_0} \Big/ \frac{d\mathrm{T}_0{}^4}{d\xi_0}.$$

Near the boundary where $\mathrm{T}_0{}^4$ is small compared with $d\mathrm{T}_0{}^4/d\xi_0$, this gives

$$\mathrm{H}_1 = 4\xi_1 + 4\mathrm{T}_1.$$

The meaning of the term $4\xi_1$ is easily seen. If $\mathrm{T}_1 = 0$, so that the temperature of any particular particle does not change, the rate of radiation will increase as the star expands, (1) because the surface increases, (2) because the material in front being spread over a larger area, offers less obstacle to the outflow of heat. Each cause contributes $2\xi_1$ to H_1.

The quantity $\delta\mathrm{T}_e/\mathrm{T}_e$ in Table I. is by definition the same as $\frac{1}{4}\mathrm{H}_1$. We have seen in § 3 that it is of about the same magnitude as ξ_1 but differs 90° in phase. Hence $\mathrm{T}_1 = \frac{1}{4}\mathrm{H}_1 - \xi_1$ will be about $\sqrt{2}$ times ξ_1, and its maximum will occur one-eighth period before greatest radiation.

* It is clear, however, that p_1 at the boundary of the star is not zero, since by theory $p_1 = -5\xi_1$, and by observation $\mathrm{T}_1 = \sqrt{2}\xi_1$ (with a difference of phase), and at the boundary p_1 must represent mainly gaseous pressure. If then we suppose that the radiative change of temperature is large compared with the adiabatic change, we seem to be dealing with too large quantities of heat. The difficulty is avoided if ionisation with a large latent heat occurs in the region here considered.

The true effective temperature depends on $\frac{1}{4}(H_1 - 2\xi_1)$, and its maximum occurs one-sixteenth of a period before greatest radiation. This perhaps explains why the observed variation of spectral type agrees in phase so nearly with the light variation.

15. *The Second-Order Terms.*—Hitherto we have neglected the square of the amplitude, and accordingly all the variations have been represented by simple harmonic terms. It is well known that the light-curve and velocity-curve of a typical Cepheid are by no means simple harmonic. The two curves are closely similar; but, as was seen in the last paragraph, we have not been able to follow out the theoretical cause of this at all fully. We shall here discuss the velocity-curve, which is the simpler to treat, since the expansion and contraction of the surface must follow closely the expansion and contraction of the adiabatic interior, whereas the periodic radiation from the surface need not (and does not) correspond to the flow of heat in the interior.

The velocity-curve can be represented by a Fourier series, of which the term $\cos 2nt$ or $\sin 2nt$, corresponding to the eccentricity of the "orbit," is of special importance. In any dynamical explanation, if we retain in the equations terms involving the square of the disturbance (that is, of the form $a^2 \cos^2 nt$), second-order terms in $\cos 2nt$ or $\sin 2nt$ will be needed to complete the solution. Thus higher harmonics necessarily appear if the amplitude is not small. From Table I. it appears that ξ_1, or $\delta R/R$, can scarcely be regarded as small; and it is at any rate not permissible to neglect the square of p_1, which in places amounts to as much as $5\xi_1$. The asymmetry of the velocity-curve is thus a natural consequence of the large amplitude which has been found.

We can go a little beyond this general explanation and show the reason for the rapid rise to a maximum and slow decline which is the striking feature of Cepheids in general. According to the phase of the harmonic in $2nt$, four cases may arise which are shown in fig. 1. The particular amplitudes 1 and $\frac{1}{3}$ are only chosen for illustration. The actual velocity-curves of the Cepheids correspond to Case (*b*), which has a fairly close resemblance to the typical luminosity- and velocity-curve. (The velocity-curve is more usually drawn inverted, velocity of recession, *i.e.* negative $d\xi/dt$, being reckoned positive.) In the following investigation we shall show that Case (*b*) is the one given by theory.

We repeat the analysis of § 5, retaining terms of the second order.

Since

$$\rho d(\xi^3) = \rho_0 d(\xi_0^3)$$

$$p = k\rho^\gamma = k\rho_0^\gamma \left(\frac{d(\xi^3)}{d(\xi_0^3)}\right)^{-\gamma} = p_0 \left(\frac{d(\xi^3)}{d(\xi_0^3)}\right)^{-\gamma}.$$

Now

$$\xi^3 = \xi_0^3 + 3\xi_0^2 \delta\xi + 3\xi_0 \delta\xi^2$$

$$= \xi_0^3 (1 + 3\xi_1 + 3\xi_1^2).$$

Hence

$$\frac{d(\xi^3)}{d(\xi_0^3)} = 1 + 3\xi_1 + 3\xi_1^2 + \frac{\xi_0}{3}\left(3\frac{d\xi_1}{d\xi_0} + 6\xi_1\frac{d\xi_1}{d\xi_0}\right)$$
$$= 1 + 3\xi_1 + \xi_0\xi_1' + 3\xi_1^2 + 2\xi_0\xi_1\xi_1'$$

$$\left(\frac{d(\xi^3)}{d(\xi_0^3)}\right)^{-\gamma} = 1 - \gamma(3\xi_1 + \xi_0\xi_1') + \tfrac{1}{2}\gamma(\gamma+1)(9\xi_1^2 + 6\xi_0\xi_1\xi_1' + \xi_0^2\xi_1'^2)$$
$$- 3\gamma\xi_1^2 - 2\gamma\xi_0\xi_1\xi_1'$$
$$= 1 - \gamma(3\xi_1 + \xi_0\xi_1') + \tfrac{1}{2}\gamma(9\gamma+3)\xi_1^2 + \gamma(3\gamma+1)\xi_0\xi_1\xi_1'$$
$$+ \tfrac{1}{2}\gamma(\gamma+1)\xi_0^2\xi_1'^2.$$

Also

$$\frac{g}{\xi^2} = \frac{g_0}{\xi_0^2} - \frac{4g_0\xi_1}{\xi_0^2} + \frac{10g_0\xi_1^2}{\xi_0^2}$$

and

$$\frac{n^2\xi_0\xi_1}{\xi^2} = \frac{n^2\xi_1}{\xi_0} - \frac{2n^2\xi_1^2}{\xi_0}.$$

Hence (7) becomes

$$\frac{1}{\rho_0\xi_0^2}\frac{d}{d\xi_0}\left[p_0\{1 - \gamma(3\xi_1 + \xi_0\xi_1') + \tfrac{1}{2}\gamma(9\gamma+3)\xi_1^2 + \gamma(3\gamma+1)\xi_0\xi_1\xi_1'\right.$$
$$\left. + \tfrac{1}{2}\gamma(\gamma+1)\xi_0^2\xi_1'^2\}\right]$$
$$= -\frac{g_0}{\xi_0^2} + \frac{4g_0\xi_1}{\xi_0^2} - \frac{10g_0\xi_1^2}{\xi_0^2} + \frac{n^2\xi_1}{\xi_0} - \frac{2n^2\xi_1^2}{\xi_0}.$$

We must now suppose that ξ_1 consists of two terms, ξ_{11} containing a factor $\cos nt$, and ξ_{12} with factor $\cos 2nt$, where ξ_{11} is of

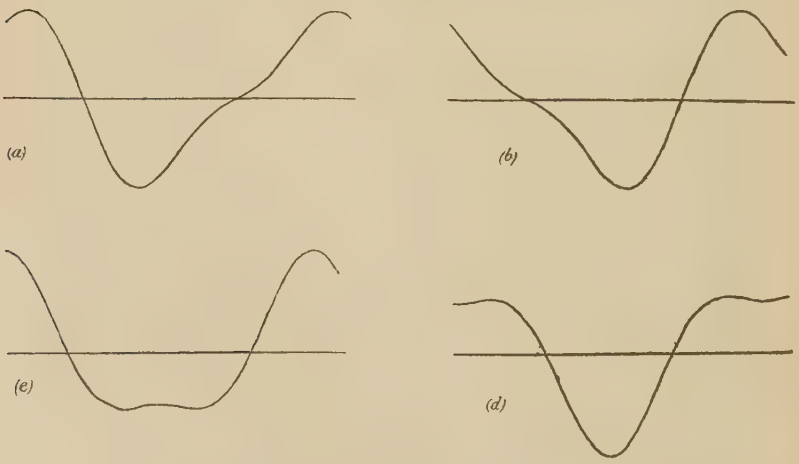

Fig. 1.—Curves with Second Harmonics.

(*a*) $y = \cos x + \frac{1}{3}\sin 2x$.
(*b*) $y = \cos x - \frac{1}{3}\sin 2x$.
(*c*) $y = \cos x + \frac{1}{3}\cos 2x$.
(*d*) $y = \cos x - \frac{1}{3}\cos 2x$.

the first order and ξ_{12} of the second order. Evidently the fourth term on the right-hand side needs to be corrected by changing n to $2n$ so far as ξ_{12} is concerned; it should read

$$(n^2\xi_{11} + 4n^2\xi_{12})/\xi_0.$$

Picking out all the terms containing cos $2nt$, we have

$$\frac{1}{\rho_0}\frac{d}{d\xi_0}\{-\gamma p_0(3\xi_{12} + \xi_0\xi_{12}')\} - (4g_0 + 4n^2\xi_0)\xi_{12}$$
$$+ \frac{1}{\rho_0}\frac{d}{d\xi_0}[p_0\{\tfrac{1}{4}\gamma(9\gamma+3)\xi_{11}^2 + \tfrac{1}{2}\gamma(3\gamma+1)\xi_0\xi_{11}\xi_{11}' + \tfrac{1}{4}\gamma(\gamma+1)\xi_0^2\xi_{11}'^2\}]$$
$$+ (5g_0 + n^2\xi_0)\xi_{11}^2 = 0.$$

The terms in ξ_{12} reduce exactly as before (with $(2n)^2$ instead of n^2), and we obtain the differential equation

$$\xi_2'' + \frac{4-\mu}{\xi_0}\xi_2' + \left(\frac{4\omega^2}{u} - \frac{a\mu}{\xi_0^2}\right)\xi_2$$
$$= \frac{1}{p_0\xi_0}\frac{d}{d\xi_0}[p_0\{\tfrac{1}{4}(9\gamma+3)\xi_1^2 + \tfrac{1}{2}(3\gamma+1)\xi_0\xi_1\xi_1' + \tfrac{1}{4}(\gamma+1)\xi_0^2\xi_1'^2\}]$$
$$+ \left(\frac{5\mu}{\gamma\xi_0^2} + \frac{\omega^2}{u}\right)\xi_1^2 \quad . \quad (36)$$

where we have written ξ_2, ξ_1 for ξ_{12}, ξ_{11}.

After some reduction the right-hand side can be written

$$Q = \xi_1^2\left(-\tfrac{1}{2}(3\gamma-1)\frac{\omega^2}{u} + \tfrac{3}{4}(\gamma-1)\frac{a\mu}{\xi_0^2}\right) + \xi_0\xi_1\xi_1'\tfrac{1}{2}(\gamma+1)\left(-\frac{\omega^2}{u} + \frac{a\mu}{\xi_0^2}\right)$$
$$+ \xi_1'^2(\tfrac{1}{4}(\gamma+1)\mu - 1) \quad . \quad (37)$$

from which it can be tabulated numerically. We use the values of ξ_1 for the solution $\omega^2 = \cdot 060$ $\gamma = \frac{10}{7}$ given in Table IV.

r.	Q.	r.	Q.
0	−0·0129	3	−0·2877
1	−0·0328	4	−0·8964
2	−0·1009		

These values of Q correspond to unit central amplitude of ξ_1, adopted in Table IV.; they must therefore be multiplied by the square of the actual central amplitude. It is, however, sufficient for our purpose to know that Q is negative. Considering the equation

$$\xi_2'' + \frac{4-\mu}{\xi_0}\xi_2' + \left(\frac{4\omega^2}{u} - \frac{a\mu}{\xi_0^2}\right)\xi_2 = Q \quad . \quad . \quad (38)$$

we must satisfy the same boundary conditions for ξ_2 as were necessary with the closely similar equation (15) for ξ_1—that is to say, the solution must give a wave of proper length to fit the star. If it were not for the term Q the wave would clearly be too short, because it has twice the frequency of the fundamental wave. To

lengthen out a wave we must delay the point at which ξ_2'' changes sign. Clearly, if we start with ξ_2 positive, the effect of the negative term Q will be to diminish ξ_2'' and to shorten the wave still further. We must therefore start with ξ_2 negative, so that Q will tend to increase ξ_2 numerically and lengthen the wave. In fact, if ξ_2 is negative, Q will compensate for the extra $\frac{3\omega^2}{u}\xi_2$ on the left side of (38) compared with (15).

We see, then, that if ξ_1 is of the form $a_1 \cos nt$, ξ_2 is of the form $-a_2 \cos 2nt$, where a_1 and a_2 are positive. Thus the displacement is

$$a_1 \cos nt - a_2 \cos 2nt$$

and the velocity is

$$-na_1 \sin nt + 2na_2 \sin 2nt,$$

or, changing the origin of time by writing $nt - 90°$ for nt, the velocity is proportional to

$$a_1 \cos nt - 2a_2 \sin 2nt,$$

corresponding to Case (*b*).

Since the eccentricity measures the strength of the second harmonic, we might expect that large values of e would correspond to large values of the amplitude $\delta R/R$. There is no particular indication of this in Table I. No doubt other factors have to be considered, such as γ, which depends on the mass of the star; but I have not been able to disentangle any relation.

16. *Broadening of the Spectral Lines.*—Although somewhat disconnected from the present investigation, it may be useful to add some remarks on the broadening of the spectral lines which might be expected at maximum and minimum light if the pulsatory theory is true.

If there is no darkening at the limb so that the star can be treated as a uniformly illuminated disc, the intensity of the light coming from parts of the star with line-of-sight velocity v to $v + dv$ will be proportional to vdv.*

With the usual law of darkening this intensity must be multiplied by

$$1 - \kappa(1 - v/V),$$

where V is the normal velocity of the surface and K is a coefficient equal to $\frac{2}{3}$ for the sun. For complete darkening at the limb $\kappa = 1$. We have therefore

$$\text{intensity} = \left(\tfrac{1}{3}v + \tfrac{2}{3}\frac{v^2}{V}\right)dv \quad \text{for } \kappa = \tfrac{2}{3}$$

$$= \frac{v^2}{V}dv \qquad \text{for } \kappa = 1.$$

* Putting v proportional to $\sin\theta$, the area of the corresponding annulus is proportional to $\cos\theta d(\cos\theta) = -\sin\theta d(\sin\theta) = -vdv$.

By integration we find that in the first case $\frac{5}{2\pi}$ of the light corresponds to velocities between 0 and $\frac{1}{2}$V : in the second case $\frac{1}{8}$ of the light corresponds to the same range.

The maximum value of V is usually about 16 km. per sec., so that the fringing of the lines will be somewhat like that due to superposition of spectra in the case of a star with a companion two magnitudes fainter differing in velocity by 8 km. per sec. It will evidently require refined observations to detect or disprove the effect.

It is by no means certain that the law of darkening here assumed will apply in the case of varying emission of light. It seems reasonable to suppose that when the emission of radiation is temporarily increased its direction will be closer to the normal to the surface, so that the light seen by us comes mainly from the centre of the disc. In that case the best chance of detecting the fringing would be at the time of minimum light. I think it has been observed that the spectral lines are sharper at maximum than at minimum, a result which would fall in with this view.

17. *Conclusions.*—1. In agreement with earlier investigators, it is concluded that the binary hypothesis of Cepheids must be ruled out, because (*a*) the distance of the centres of the components would have to be less than the radius of one of them, (*b*) because there is a uniform relation between the period and density which seems to point to a cause intrinsic in the star (§ 3).

2. The hypothesis that the variation is due to a symmetrical dilatation and contraction of a single star leads to results in agreement with observation in the following respects :—

(*a*) The absolute value of the period, which can be determined theoretically with a factor of uncertainty not greater than 2 (§ 8).

(*b*) The advance of spectral type towards the red with increasing luminosity (§ 11).

(*c*) The asymmetric form of the velocity-curve (§ 15).

3. Owing to the high opacity, the vibrations throughout the greater part of the interior are very nearly adiabatic (§ 9). For the same reason, the dissipation of energy due to periodic flow of heat is comparatively small ; the time of decay of a pulsation from this cause is of the order 1500 years (§ 12).

4. In the interior the outward flow of heat is a maximum at the time of greatest compression. In the non-adiabatic outer layers the maximum must occur later ; but it has not been possible to obtain mathematically the observed law that at the surface the delay amounts to a quarter-period—which is one of the best-known characteristics of the Cepheids (§ 14).

5. In the Cepheids examined the amplitude of the pulsation ranges from about 5 per cent. to 11 per cent. of the radius. The light-range is roughly proportional to the relative change of radius (§ 3).

6. Calculations of the densities of particular Cepheids show that the product $P\sqrt{\rho}$ is approximately constant. This relation should be approximately true on almost any pulsatory theory. On the present theory there should be a slight increase of $P\sqrt{\rho}$ with

increasing mass, which is perhaps confirmed by the calculations based on Adams' and Joy's determinations of spectral type (§ 8).

7. If the star's energy is derived solely from contraction, the change of period due to increasing density should be easily measurable. Since the observed change is much too small, it appears to follow that the star must have some other source of energy (§ 10).

8. For stars of period greater than three days the central density is less than $\frac{1}{10}$ water, and the condition approximates to that of a perfect gas throughout. For cluster-variables with periods less than a day the deviations from a perfect gas will have an important influence. (The effect is to increase γ in the equation $p_1 = \gamma\rho_1$, and consequently the period is shorter than if the properties of a gas were retained) (§ 3).

9. The suggestion that Cepheid variation may occur in all stars at the time when the central temperature reaches a certain value (and consequently the temperatures at other corresponding points have definite values) appears to be untenable. The numerical relations suggest that the occurrence of variation is determined by conditions in the outside layers of the star (§ 13).

On the Variable Star B.D. + 39° 3476 = Piazzi XVIII. 153.

R.A. = 18 h 33 m 19 s Dec. = + 39° 32′·8 (1855)
R.A. = 18 34 48 Dec. = + 39 34·8 (1900)

By A. Stanley Williams.

The variability of this star was announced by the Rev. T. E. Espin in a paper communicated by him at the December meeting of the Society. It is No. 3 of his list. The region of the sky including the star is covered by a good many of my photographs taken with a 4·4-inch portrait lens, and at Mr. Espin's request I have examined all those at present accessible, ten in number, and have made careful comparisons of the photographic brightness of the variable with the following two comparison stars:—

Star.	B.D. No.	B.D. Mag.	Photographic Magnitude.
A	+ 39° 3463	7·7	7·34
B	+ 39° 3479	7·8	7·74

The comparisons were made by "steps" in the usual manner in which visual comparisons are made. The results are contained in the column headed (1) in the table which follows. The order of the plates was then changed, and a second and independent series of comparisons was made with the same comparison stars. These

are given in column (2). It will be seen that in every case the results of columns (1) and (2) agree within a step (0·05 mag.), excepting those of the plate dated 1899 Sept. 28. A third independent set of comparisons on this plate gave the result A5*v*3B. This agrees with the comparisons in column (2), and has been adopted. The last column of the table gives the corresponding photographic magnitudes of the variable.

Photographic Brightness of B.D.+39° 3476.

Date.	Comparisons. (1)	Comparisons. (2)	Photographic Magnitude.
1899 Sept. 28	A3*v*5B	A5*v*3B	7·59
Dec. 31	A0*v*8B	A0*v*8B	7·34
1900 Sept. 2	A2*v*6B	A3*v*5B	7·46
,, 19	A6*v*2B	A5*v*3B	7·61
,, 21	A6*v*2B	A5*v*3B	7·61
,, 25	A6*v*2B	A5*v*3B	7·61
Nov. 15	A4*v*4B	A3*v*5B	7·51
1901 Nov. 15	A4*v*4B	A3*v*5B	7·51
1904 Sept. 10	A3*v*5B	A2*v*6B	7·46
Oct. 8	A8*v*0B	A8*v*0B	7·74

The adopted photographic magnitudes of the two comparison stars given above were derived by Mr. Espin from measures of two photographs with a "split lens," and kindly communicated by him to me. The photographic difference of magnitude is 0·40 mag. Assuming the value of one of my "steps" to be 0·05 mag., which I think cannot be far wrong, the photographic difference between the two stars from my estimates would be likewise 0·40 mag.

It will be seen that the above results confirm the variability of the star. Of this there can be no doubt whatever, the changes on my plates being quite conspicuous, and beyond the likelihood of photographic differences in the plates. In this connection it may be pointed out that the results for the three nights of Sept. 19, 21, and 25 of 1900, when little or no change might be expected in a variable of this kind, agree exactly to one-fortieth of a magnitude.

St. Mawes:
1919 *Jan.* 4.

The Short-period Variable RR Ceti. By C. Martin and H. C. Plummer.

1. The variability of RR Ceti was discovered by E. R. v. Oppolzer* in 1906, the provisional number being 122·1906. Other designations are B.D. +0°·249, and 012700 on the Harvard system. The star was observed visually in 1908 by L. Pracka,† who determined the nature of the variation and found the period $0^{d}\cdot553022$. The comparison of his epoch of maximum, J.D. 241 7501·455 with that inferred from the present observations after the lapse of 7913 periods furnishes the elements

$$\text{J.D. } 242\ 1877\cdot531 + 0\cdot553024\ E,$$

which agree well with the earlier determination, and have been adopted in the reductions.

2. The magnitudes of the comparison stars have been derived from a single plate exposed on the region of the variable and on the χ Persei cluster,

Table I.

B.D.+0°.	*m*.	Corr.	*m'*.	P.E.	Range.
243	10·32	+·006	10·33	±·012	·08
246	10·75	−·016	10·73	±·019	·10
244	11·00	+·008	11·01	±·021	·14
253	11·00	+·001	11·00	±·013	·10
247	11·38	·000	11·38	±·016	·11

for which Schwarzschild's magnitudes have been used. In this way the magnitudes *m* in Table I. were obtained and adopted in the reduction of the variable. The plate residuals give the small corrections incorporated in the column *m'*, the probable error for a single plate, and the extreme range shown in the last column. These residuals are derived from 41 exposures.

3. But a remark is necessary. Since RR Ceti is nearly on the equator and culminates less than an hour before the upper culmination of χ Persei, it was impossible to make the exposures on the two regions at the same altitude and near the same time. The Z.D. of RR Ceti was in fact 53° and of χ Persei at the following exposure 7°. The photographic magnitudes observed should therefore be about a third of a magnitude fainter than according to Schwarzschild's system, but the correction is very uncertain and has not been applied.

4. The results from the 41 exposures on the variable are given in Table II. In the second and third columns are recorded the astronomical date and G.M.T., together with the Julian day and decimal fraction, corresponding to the middle of each exposure,

* *A.N.*, 4131. † *A.N.*, 4335.

the length of which is shown in the fifth column. The phase in days, given in the fourth column, is based on the elements adopted in § 1. The residuals in the seventh column are taken graphically

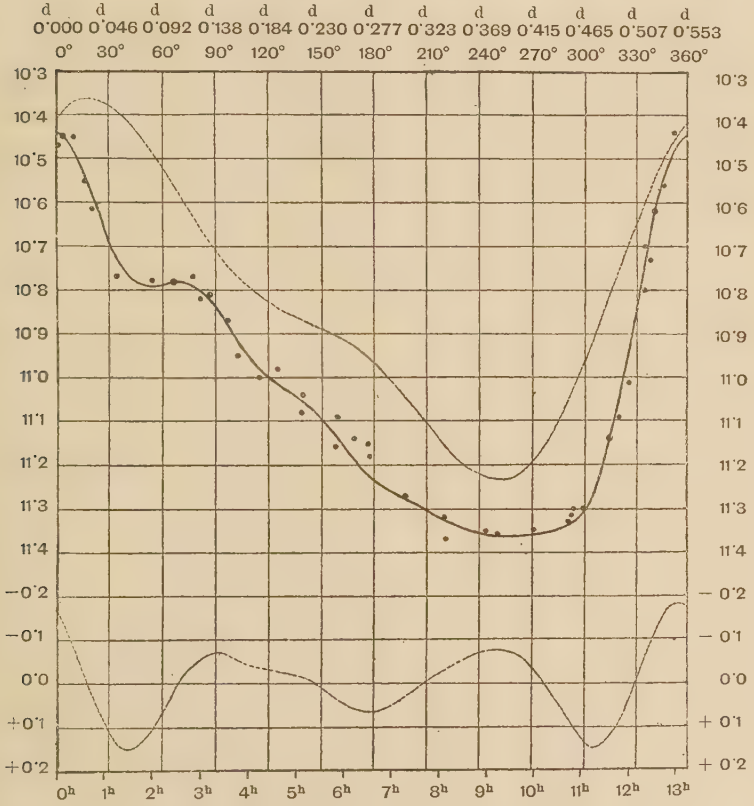

Fig. 1.—Photographic Light Curve of RR Ceti.

from the comparison of the photographic magnitudes of the variable in the sixth column with the complete curve in fig. 1. They indicate a probable error of ±·020 for a single measured magnitude.

[Table

TABLE II.

Serial No.	Date G.M.T.				Julian Day.	Phase in days.	Exposure.	Magn.	Obs. —Curve.	Images.
	1916.	d	h	m	2421		m.			
1	Sept.	19	11	43	126·489	·518	30	10·73	+·05	Good.
2		28	11	26	135·476	·103	34	10·78	·00	Fair.
3		28	12	9	135·506	·133	34	10·81	−·01	Fair.
4	Oct.	25	9	4	162·378	·460	40	11·30	−·01	Fair.
5		25	9	49	162·409	·491	40	11·09	+·04	Good.
6		25	10	42	162·447	·529	40	10·56	+·01	Good.
7		25	11	27	162·477	·006	40	10·45	·00	Fair.
	1918.									
8	Aug.	31	11	59	837·499	·339	40	11·37	+·04	Fair.
9		31	12	47	837·533	·373	40	11·35	−·01	Fair.
10	Sept.	2	11	57	839·498	·126	40	10·82	+·01	Good.
11		2	12	42	839·530	·158	40	10·95	+·03	Good.
12		11	11	49	848·492	·271	15	11·15	−·08	Fair.
13		27	10	48	864·451	·193	40	10·98	−·03	Good.
14		27	11	20	864·472	·214	17	11·04	−·02	Fair.
15		30	11	24	867·475	·451	40	11·30	−·03	Good.
16		30	12	9	867·506	·482	40	11·14	·00	Fair.
17		30	12	51	867·536	·512	23	10·80	+·05	Fair.
18	Oct.	7	11	21	874·472	·259	40	11·14	−·05	Good.
19		10	12	0	877·500	·522	40	10·62	·00	Good.
20		10	12	45	877·532	·001	40	10·47	+·03	Good.
21		10	13	30	877·563	·032	40	10·62	+·04	Good.
22	Nov.	5	8	32	903·355	·385	40	11·36	·00	Good.
23		5	9	16	903·386	·416	40	11·35	−·01	Good.
24		5	10	0	903·417	·447	40	11·33	−·01	Good.
25		5	11	39	903·486	·516	40	10·70	·00	Good.
26		6	7	38	904·319	·243	40	11·16	+·02	Fair.
27		6	8	22	904·348	·272	40	11·18	−·05	Good.
28		6	9	6	904·379	·303	40	11·27	−·01	Good.
29		6	9	55	904·413	·337	40	11·32	−·01	Good.
30		8	7	29	906·313	·025	40	10·55	+·01	Fair.
31		8	8	12	906·341	·053	40	10·77	+·04	Good.
32		8	8	56	906·372	·084	40	10·78	−·01	Good.
33		8	9	43	906·406	·118	40	10·77	−·02	Good.
34		8	10	28	906·437	·149	40	10·87	−·01	Good.
35		8	11	12	906·466	·178	40	11·00	+·02	Good.
36		8	12	1	906·501	·213	40	11·08	+·02	Good.
37		8	12	45	906·532	·244	40	11·09	−·05	Good.
38		26	10	24	924·434	·449	40	11·31	−·02	Fair.
39	Dec.	4	6	23	932·266	·539	40	10·44	−·04	Good.
40		4	7	6	932·296	·016	40	10·45	−·03	Good.
41		5	8	2	933·334	·501	28	11·01	+·07	Fair.

5. The complete curve shown in the figure represents the equation

$$m = 11^{\cdot}02 + 0^{\cdot}37 \sin(\theta + 229^{\circ}) + 0^{\cdot}13 \sin(2\theta + 264^{\circ})$$
$$+ 0^{\cdot}09 \sin(3\theta + 288^{\circ}) + 0^{\cdot}06 \sin(4\theta + 296^{\circ}) + 0^{\cdot}03 \sin(5\theta + 291^{\circ}),$$

where θ is reckoned from the adopted epoch of maximum and its period 2π corresponds with the period of the star. In the same figure the upper curve, which is raised by $0^{m}\cdot2$, exhibits the result of omitting the third, fourth, and fifth harmonics. The lowest curve represents the sum of these three harmonics separately. By a change of epoch the above equation can be reduced to the form

$$m = 11^{\cdot}02 - 0^{\cdot}37 \cos\phi + 0^{\cdot}13 \cos(2\phi - 104^{\circ})$$
$$+ 0^{\cdot}09 \cos(3\phi - 39^{\circ}) + \ldots$$

giving $\phi_2 = 104^{\circ}$, $\phi_3 = 39^{\circ}$ on the (ϕ_2, ϕ_3) diagram of Mr. Phillips. The situation of this point associates RR Ceti with RZ Cephei among the merihemeral stars, and with V Lacertæ among those of longer period (5 days).

6. Some sentences may be quoted from Pracka's description of the visual light curve for comparison with the photographic light curve in fig. 1. "Die Lichtcurve zeigt im Maximum eine 29 Minuten dauernde Lichtkonstanz ($8^{m}\cdot2$)." The few photographic observations at this point confirm this constancy at maximum as against the curve as drawn. "14 Min. nach dem theoretischen Maximum fängt die Lichtabnahme an, welche nach $1^{h}\ 40^{m}$ bei $8^{m}\cdot72$ aufhört. Von diesem Momente an bleibt das Licht bis $3^{h}\ 23^{m}$ (vom Maximum gerechnet) konstant, um dann wieder langsam abzunehmen, bis nach $5^{h}\ 18^{m}\ 9^{m}\cdot0$ erreicht wird." The stationary phase at $2\frac{1}{2}^{h}$ after maximum is therefore equally shown by the visual and the photographic observations. "In der folgenden Zeit bleibt das Licht entweder konstant, oder nimmt, was trotz der sehr geringen Amplitude ($0^{m}\cdot1$) wahrscheinlicher ist, noch sehr langsam ab, und $11^{h}\ 21^{m}$ nach dem Maximum tritt dann mit $9^{m}\cdot1$ das eigentliche Minimum ein. Dann fängt die zuerst langsamere, später aber sehr rapide Lichtzunahme an, bis nach $1\frac{1}{2}$ Stunden wieder die Maximalhelligkeit erreicht wird." This implies a nearly stationary phase of 3^{h} on either side of $8^{h}\ 20^{m}$ after maximum. The flat minimum shown by the photographic observations is not nearly so long as 6^{h}, and the discrepancy may be attributed to a marked change in the blue light which the eye has little power to detect, but which has been shown clearly in similar cases by spectrographic observations. On the whole, the agreement between the visual and photographic results is tolerably close, and the range ($0^{m}\cdot9$) appears to be nearly the same for both.

7. The separate representation of the three higher harmonics is seen to be of interest when fig. 1 is compared with the corresponding figure * for RZ Cephei. It will then be apparent that

* *M.N.*, 78, 157.

exactly the same type of disturbance is involved in both cases, the only difference consisting in the scale and the displacement relative to the epoch of maximum. It will appear further that this feature is not confined to the two stars RR Ceti and RZ Cephei. The variation may be represented by the formula

$$\Delta m = -0{\cdot}48 \cos 3\phi - 0{\cdot}31 \cos 4\phi - 0{\cdot}21 \cos 5\phi,$$

the coefficients being expressed in an arbitrary scale and the origin of ϕ being open to choice. The corresponding curve is shown in fig. 2.

8. To compare this form with the results of observation it is necessary to multiply Δm by a suitable factor and to change the

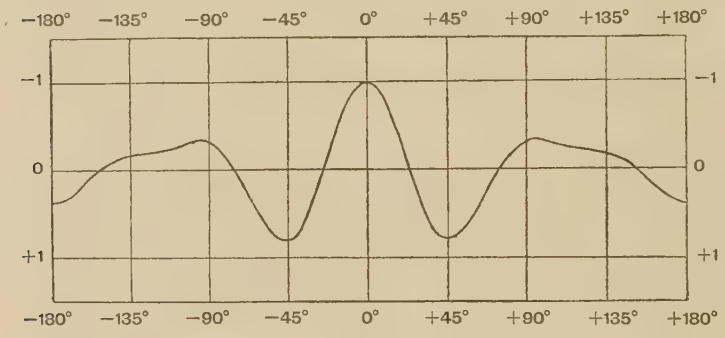

Fig. 2.

phase by substituting $\theta + \alpha$ for ϕ, where α is open to choice. A few examples will be given.

(a) The factor 0·18 and $\phi = \theta + 6°$ lead to

$$0{\cdot}09 \sin(3\theta + 288°) + 0{\cdot}06 \sin(4\theta + 294°) + 0{\cdot}04 \sin(5\theta + 300°),$$

and the corresponding terms for RR Ceti given above are

$$0{\cdot}09 \sin(3\theta + 288°) + 0{\cdot}06 \sin(4\theta + 296°) + 0{\cdot}03 \sin(5\theta + 291°).$$

(b) The factor 0·09 and $\phi = \theta - 93°$ lead to

$$0{\cdot}04 \sin(3\theta + 351°) + 0{\cdot}03 \sin(4\theta + 258°) + 0{\cdot}02 \sin(5\theta + 165°),$$

and the corresponding terms for RZ Cephei are

$$0{\cdot}04 \sin(3\theta + 343°) + 0{\cdot}03 \sin(4\theta + 257°) + 0{\cdot}02 \sin(5\theta + 177°).$$

(c) The factor 0·23 and $\phi = \theta + 6°$ lead to

$$0{\cdot}11 \sin(3\theta + 288°) + 0{\cdot}07 \sin(4\theta + 294°) + 0{\cdot}05 \sin(5\theta + 300°),$$

and the corresponding terms * for RS Boötis are

$$0{\cdot}11 \sin(3\theta + 277^\circ) + 0{\cdot}07 \sin(4\theta + 297^\circ) + 0{\cdot}05 \sin(5\theta + 333^\circ).$$

(*d*) The factor 0·32 and $\phi = \theta$ lead to

$$0{\cdot}15 \sin(3\theta + 270^\circ) + 0{\cdot}10 \sin(4\theta + 270^\circ) + 0{\cdot}07 \sin(5\theta + 270^\circ),$$

and the corresponding terms † for XZ Cygni are

$$0{\cdot}16 \sin(3\theta + 258^\circ) + 0{\cdot}09 \sin(4\theta + 269^\circ) + 0{\cdot}07 \sin(5\theta + 290^\circ).$$

(*e*) The factor 0·16 and $\phi = \theta + 10^\circ$ lead to

$$0{\cdot}08 \sin(3\theta + 300^\circ) + 0{\cdot}05 \sin(4\theta + 310^\circ) + 0{\cdot}03 \sin(5\theta + 320^\circ),$$

and the corresponding terms ‡ for SW Draconis are

$$0{\cdot}07 \sin(3\theta + 307^\circ) + 0{\cdot}05 \sin(4\theta + 302^\circ) + 0{\cdot}04 \sin(5\theta + 310^\circ).$$

(*f*) The factor 0·23 and $\phi = \theta + 5^\circ$ lead to

$$0{\cdot}11 \sin(3\theta + 285^\circ) + 0{\cdot}07 \sin(4\theta + 290^\circ) + 0{\cdot}05 \sin(5\theta + 295^\circ),$$

and RR Lyræ gives the terms §

$$0{\cdot}11 \sin(3\theta + 286^\circ) + 0{\cdot}08 \sin(4\theta + 287^\circ),$$

but the fifth harmonic has not been recorded, its coefficient being less than 0·02.

9. The result is that among seven stars of the merihemeral group which have been carefully studied this standard form of secondary disturbance can be clearly traced in five cases; in one (RR Lyræ) it is imperfect in respect of the fifth harmonic, and in one (SU Draconis) the disturbance seems to be of a different type. The prevalence of one common form is interesting in itself, and lends confirmation, if that were necessary, to the reality of the disturbances as permanent features of the light curves, and to the accuracy of the observations. The harmonics beyond the fifth enter doubtless into the disturbance, but are generally too small to be traced with any certainty. Where considerable coefficients are associated with harmonics beyond the sixth in this class of stars their reality may well be open to doubt, not through any failure in the observations, but on account of instability in the light variations in different periods. It is hoped that a further investigation of this question may be made.

* *M.N.*, 78, 641. † *M.N.*, 74, 229.
‡ *M.N.*, 73, 445. § *M..N*, 75, 572.

Magnitude Observations of Five Wolf-Rayet Stars.

By C. Martin and H. C. Plummer.

1. The position of exceptional interest held by the fifth-type stars suggested an inquiry into the constancy or variability of their light. Five stars of this type have been observed photographically at intervals extending over two years, and the results are appended to this paper. All the stars lie close together in the constellation Cygnus, and are within one degree of the central line of the Milky Way. The tabulated results give the date with G.M.T., the corresponding Julian day with decimal fraction for the middle of each exposure, the duration of the exposure in minutes, the concluded magnitude under m, and under Δm the deviation of the latter from the mean. Following this record is the information relative to the comparison stars, giving the B.D. designation, the adopted magnitude m, the magnitude m' resulting from the application of the mean residual from all the plates, and the numerical average of these residuals. The first two stars, B.D. $+35°\cdot4001$ and 4013, are both on the same set of plates and reduced with the same comparison stars. The magnitudes of the comparison stars are obtained from plates similarly exposed on the regions and on the χ Persei cluster, and are thus referred to Schwarzschild's system for stars in that cluster.

2. The means for each season's observations are collected in Table I., the number of measures entering into each being added in

Table I.

Star.	1916. m.	1917. m.	1918. m.	D.	H.	D−H.	H−B.
B.D. $+35°\cdot4001$	7·85(18)	7·95(7)	7·97(3)	7·88	7·80	+0·08	−0·70
4013	7·96(18)	8·01(7)	8·05(3)	7·98	7·94	+0·04	−0·06
$+36°\cdot3956$	8·06(9)	8·06(10)	8·10(2)	8·06	7·94	+0·12	−0·06
3987	7·87(8)	7·83(6)	7·78(2)	7·84	7·97	−0·13	−0·13
$+38°\cdot4010$	8·32(11)	8·45(8)	8·41(5)	8·38	8·04	+0·34	−0·66

brackets. Under D. are given the complete means for the Dunsink photographic observations, under H. the Harvard photometric magnitudes,* and in the last two columns the differences between the latter and the Dunsink magnitudes on one side and the B.D. magnitudes on the other. Although three distinct systems of magnitudes are involved, the long interval since the B.D. estimates were made, taken in conjunction with this comparison, negatives the possibility of a true secular change such as might be suggested by the run of the annual means. In the period covered by the present observations the first two stars seem to have been growing fainter, and the fourth has possibly grown

* *Harvard Annals*, **56**, 180.

brighter. But it is necessary to consider each individual case by itself.

3. *B.D.* + 35°·4001.—The run of the deviations from the mean in this case shows at once that the star is variable, because after the first observation there is only one change of sign, occurring at the beginning of 1916 October. Thus we have:—

Before 1916 Oct. 1	17 obsns.	mean mag. 7·84
After „	11 „	„ „ 7·95

The average deviation is ± 0^{m}·056, and the type of variation appears to be slow.

4. *B.D.* + 35°·4013.—The variability of this star is not so obvious, but is shown by the average deviation ± 0^{m}·050 from the mean. The type of variation is apparently quick. This is seen from the observations of 1916 July 28, and Sept. 28 and 29. The changes on each of these nights are so small that it is necessary in forming a judgment to notice carefully that similar changes do not occur with the other stars in the course of a single night.

5. *B.D.* + 36°·3956.—The average deviation from the mean is ± 0^{m}·030, and does not suggest any variation. The two observations of 1917 Oct. 17 unite in giving a magnitude 0^{m}·09 fainter than the mean of the rest, but this cannot be regarded as conclusive.

6. *B.D.* + 36°·3987.—The average deviation from the mean, ± 0^{m}·024, is so small as to suggest a practically constant magnitude. The annual means, on the other hand, have the systematic tendency which is shown in Table I., and the star may have been growing slightly brighter during the period covered by the observations. The variation if real is very slow.

7. *B.D.* + 38°·4010.—This star is clearly variable, as shown by two nights' observations:

1916 Sept. 19	5 obsns.	mean mag. 8·28
1917 „ 20	4 „	„ „ 8·49

The average deviation ± 0^{m}·062 from the mean is also quite incompatible with a constant magnitude.

8. We may conclude that of the five stars examined three are fairly certainly variable and the other two are possibly so. But the range of variation is in all cases small, perhaps a quarter of a magnitude or less. This will serve to show the order of accuracy needed to deal further with this important class of objects. It seems clearly suggested that at least the majority of the Wolf-Rayet stars are variable within narrow limits. The magnitudes of the comparison stars seem to be tolerably stable, and through them it should not be difficult to reduce the present observations of the Wolf-Rayet stars to any other system of magnitudes whenever it is desired to do so.

Date. G.M.T.			Julian Day.	Exposure.	B.D. +35°·4001.		B.D. +35°·4013.	
					m.	Δ*m.*	*m.*	Δ*m.*
1916	h	m	2421					
July 25	11	38	070·485	30	7·91	+·03	7·85	−·13
28	11	14	073·468	30	7·86	−·02	8·06	+·08
	11	51	073·494	30	7·85	−·03	7·96	−·02
	12	24	073·517	30	7·81	−·07	7·97	−·01
Aug. 2	10	37	078·443	30	7·81	−·07	7·99	+·01
4	10	26	080·435	15	7·85	−·03	8·05	+·07
5	10	52	081·453	30	7·76	−·12	7·91	−·07
7	12	44	083·532	30	7·85	−·03	7·95	−·03
	13	14	083·552	30	7·83	−·05	7·94	−·04
30	11	18	106·471	12	7·87	−·01	8·00	+·02
Sept. 22	9	23	129·391	26	7·87	−·01	7·87	−·11
	9	50	129·410	26	7·82	−·06	7·95	−·03
28	7	59	135·333	26	7·81	−·07	8·06	+·08
	8	30	135·354	26	7·84	−·04	7·98	·00
	9	9	135·381	26	7·84	−·04	7·92	−·06
29	8	15	136·343	30	7·83	−·05	7·90	−·08
	8	47	136·366	30	7·85	−·03	8·01	+·03
Oct. 3	8	17	140·345	18	7·97	+·09	7·97	−·01
1917								
Sept. 7	9	13	479·384	30	7·92	+·04	7·98	·00
	9	53	479·412	30	7·90	+·02	7·93	−·05
	10	30	479·438	30	7·97	+·09	8·02	+·04
	11	11	479·465	30	7·94	+·06	7·99	+·01
	11	49	479·492	30	7·97	+·09	8·02	+·04
Oct. 9	7	50	511·327	30	7·99	+·11	8·10	+·12
	8	21	511·347	30	7·94	+·06	8·03	+·05
1918								
Sept. 11	9	55	848·413	30	7·97	+·09	8·03	+·05
	10	26	848·435	30	7·99	+·11	8·07	+·09
28	9	7	865·379	30	7·94	+·06	8·06	+·08
				(Means)	7·88	±·056	7·98	±·050

Comparison Stars.

	m.	*m'.*	Av. residual.
B.D. +35°·3995	7·71	7·69	±·019
+35°·4006	7·76	7·78	±·018
+36°·3933	8·40	8·40	±·028
+35°·4000	8·67	8·67	±·023

B.D. +36°·3956.

Date. G.M.T.			Julian Day.	Exposure.	*m.*	Δ*m.*
1916	h	m	2421	m		
July 28	13	6	073·546	30	8·05	−·01
Aug. 2	11	20	078·472	30	8·04	−·02
5	11	31	081·479	30	8·07	+·01
21	10	5	097·421	20	8·07	+·01
	10	25	097·435	20	8·08	+·02
	10	52	097·453	20	8·04	−·02
	11	16	097·469	30	8·02	−·04
	11	42	097·488	20	8·09	+·03
Sept. 28	10	19	135·431	20	8·08	+·02

Date. G.M.T.			Julian Day.	Exposure.	*m.*	Δ*m.*
1917	h	m	2421	m		
Sept. 11	8	43	483·364	20	8·01	−·05
	9	5	483·379	20	8·05	−·01
	9	31	483·397	20	8·07	+·01
	9	51	483·411	20	8·04	−·02
	10	19	483·431	20	8·05	−·01
	10	41	483·446	20	8·02	−·04
Oct. 9	8	57	511·373	20	8·04	−·02
	9	19	511·389	20	8·02	−·04
17	7	50	519·327	30	8·15	+·09
	8	22	519·348	30	8·14	+·08
1918						
Sept. 26	8	51	863·369	20	8·11	+·05
	9	15	863·385	24	8·09	+·03
				(Means)	8·06	±·030

Comparison Stars.

	m.	*m'.*	Av. residual.
B.D. +36°·3958	7·57	7·57	±·012
+36·3959	7·97	7·97	±·014
+36·3933	8·38	8·37	±·013
+36·3946	8·65	8·66	±·014

B.D. +36°·3987.

Date. G.M.T.			Julian Day.	Exposure.	*m.*	Δ*m.*
1916	h	m	2421	m		
July 27	12	21	072·514	34	7·88	+·04
Aug. 3	10	38	079·444	30	7·86	+·02
7	10	51	083·453	30	7·87	+·03
Sept. 1	9	27	108·394	30	7·84	·00
	9	57	108·415	30	7·89	+·05
	10	35	108·442	30	7·85	+·01
	11	5	108·462	30	7·89	+·05
29	9	29	136·396	30	7·84	·00

Date. G.M.T.			Julian Day.	Exposure.	*m.*	Δ*m.*
1917	h	m	2421	m		
Sept. 13	8	26	485·349	30	7·84	·00
	9	2	485·376	15	7·84	·00
	10	0	485·417	30	7·85	+·01
	10	32	485·439	30	7·83	−·01
Oct. 10	7	39	512·320	30	7·79	−·05
	8	11	512·340	30	7·84	·00
1918						
Nov. 6	6	51	904·286	30	7·79	−·05
8	6	43	906·281	30	7·77	−·07
				(Means)	7·84	±·024

Comparison Stars.

	m.	*m'.*	Av. residual.
B.D. +37°·3866	7·65	7·64	±·009
+37·3863	7·80	7·81	±·017
+36·3994	8·21	8·19	±·029
+37·3868	8·77	8·78	±·014

B.D. + 38°·4010.

Date. G.M.T.			Julian Day.	Exposure.	*m.*	Δ*m.*
1916	h	m	2421	m		
July 25	12	31	070·521	34	8·39	+ ·01
Aug. 3	11	18	079·471	30	8·35	− ·03
7	11	31	083·479	30	8·36	− ·02
	12	2	083·501	30	8·37	− ·01
Sept. 6	10	27	113·436	17	8·33	− ·05
19	8	25	126·351	30	8·28	− ·10
	8	55	126·371	30	8·28	− ·10
	9	33	126·398	30	8·29	− ·09
	10	4	126·420	30	8·27	− ·11
	10	41	126·446	30	8·30	·08
Oct. 25	7	26	162·310	30	8·28	− ·10

Date. G.M.T.			Julian Day.	Exposure.	*m.*	Δ*m.*
1917	h	m	2421	m		
Sept. 19	10	4	491·420	30	8·44	+ ·06
20	8	41	492·362	30	8·47	+ ·09
	9	11	492·382	30	8·46	+ ·08
	9	52	492·411	30	8·52	+ ·14
	10	22	492·432	30	8·52	+ ·14
Oct. 10	8	50	512·368	30	8·41	+ ·03
	9	12	512·383	15	8·34	− ·04
Nov. 12	7	10	545·299	24	8·43	+ ·05
1918						
Sept. 10	9	47	847·408	30	8·38	·00
	10	18	847·430	30	8·40	+ ·02
30	9	19	867·389	34	8·48	+ ·10
Oct. 7	8	3	874·335	34	8·40	+ ·02
	8	38	874·360	34	8·40	+ ·02
				(Means)	8·38	± ·062

Comparison Stars.

	m.	*m'.*	Av. residual.
B.D. + 38·4003	7·94	7·94	± ·024
+ 38·4012	8·16	8·16	± ·022
+ 38·4026	8·79	8·78	± ·013
+ 38·4019	8·96	8·97	± ·011

Proper Motions of the Stars in Zone 24° – 32° N. Declination, in relation to Spectral Type. By Sir F. W. Dyson and W. G. Thackeray.

The Greenwich Catalogue for 1910 includes stars to the ninth magnitude between the limits of declination +24° and +32° contained in the Catalogues of the Astronomische Gesellschaft.

Delay in the printing of the Catalogue has arisen in consequence of the war, but this delay has allowed a considerable improvement to be made in the Catalogue. Thanks to the kindness of Professor Pickering and Miss Cannon, who have forwarded in advance of publication the results from the new Henry Draper Catalogue, the spectral types for 6500 of the stars (roughly for all those brighter than $8^m{\cdot}7$) have been given, and in addition recent Harvard determinations of magnitude. The Harvard magnitude scale is used throughout by the use of the corrections to the Bonn magnitudes given in Table xix. vol. lxxii., *Annals of Harvard College Observatory.*

Distribution of Stars.

The zone cuts the Milky Way at R.A. $5^h\ 30^m$ and $19^h\ 30^m$. On the north side it reaches the Galactic pole, but on the south does not reach a lower Galactic latitude than −35°. Between 22^h and 3^h the zone is nearly parallel to the Galaxy, and distant 30° from it.

A general idea of the distribution of the stars is obtained from the following tables:—

	R.A. 23 h.–2 h. Gal. lat. −33°.	5 h.–8 h. +10°.	11 h.–14 h. +80°.	18 h.–21 h. +3°.
B8, B9, and A0	61	279	19	340
A2–F5	125	170	87	145
F8–G5	230	179	240	140
K0	151	137	138	142
M	26	18	11	25

The most conspicuous feature of the table is the diminution in number of B8–A0 stars as distance from the Galaxy increases.

The F8–G5 stars show, though not to such a pronounced extent, the opposite distribution. They are most plentiful at the Galactic pole. The K0 stars are distributed very uniformly. The following table gives the details of the distribution of stars of different types throughout the zone. (Table I.)

TABLE I.

Distribution of Stars of Different Spectral Types for each hour of Right Ascension.

R.A. h	B.	Bo.	B2.	B3.	B5.	B8.	B9.	A.	Ac.	A2.	A3.	A5.	F.	Fo.	F2.	F5.	F8.	G.	Go.	G5.	K.	Ko.	K2.	K5.	Ma.	Mb.	Mc.	Md.	Galac. Lat. °
0	...	...	...	...	...	2	2	...	15	20	3	9	2	14	7	25	19	4	12	54	...	42	20	6	8	2	...	1	− 35
1	...	...	...	...	...	1	1	...	13	23	5	13	...	16	9	22	13	...	14	36	1	52	13	8	5	4	...	...	33
2	...	...	...	1	...	6	4	...	21	23	8	5	1	17	7	33	8	3	23	36	...	51	11	4	3	1	1	1	29
3	...	1	...	1	4	3	15	3	47	32	10	10	...	10	3	13	15	1	18	21	...	34	11	5	5	...	...	...	21
4	...	...	...	2	2	1	13	7	30	12	6	1	1	10	5	15	13	4	9	19	2	17	5	6	2	...	...	...	12
5	2	...	4	5	12	23	29	23	52	25	20	11	3	10	8	28	18	1	7	29	1	39	13	8	3	...	...	...	− 1
6	1	...	...	1	...	9	26	13	92	48	14	9	6	11	5	19	12	2	17	38	2	44	24	8	7	...	...	...	+ 10
7	...	1	...	...	1	3	8	5	42	23	7	10	3	18	9	27	12	6	11	36	5	58	17	7	7	1	...	...	22
8	...	...	...	...	...	...	2	3	19	21	10	10	1	11	11	21	8	4	15	31	...	53	18	9	3	1	1	...	35
9	...	...	...	...	...	...	2	1	8	9	1	8	2	9	3	17	24	6	21	33	1	70	12	3	4	...	...	...	48
10	...	...	...	...	...	...	1	1	6	5	4	4	1	11	6	22	20	2	29	37	1	64	8	5	5	...	...	...	61
11	...	...	...	...	...	...	...	...	6	5	4	3	1	11	7	21	17	5	10	32	...	43	7	4	2	1	...	...	75
12	...	...	...	...	...	...	...	...	9	10	10	5	1	7	6	24	20	3	37	53	...	49	16	5	5	...	...	...	87
13	...	...	...	...	...	...	1	1	3	6	3	6	...	6	6	15	15	3	12	44	5	46	4	6	3	...	...	...	79
14	...	...	...	...	...	...	2	...	9	8	1	...	4	10	7	16	11	6	13	24	6	38	8	8	7	1	...	...	66
15	...	...	...	...	1	...	...	1	12	7	1	2	...	4	4	14	23	...	17	44	...	64	19	17	1	1	...	1	53
16	...	...	...	...	...	...	...	...	9	4	10	5	...	11	9	23	21	1	9	33	...	48	20	11	7	2	...	...	40
17	...	...	...	...	...	...	3	2	29	25	12	6	...	12	9	20	13	3	10	25	...	50	16	14	10	3	...	...	27
18	...	...	...	7	1	8	19	11	41	32	8	11	2	12	3	7	10	2	14	33	6	55	20	7	5	1	...	1	15
19	...	1	1	3	8	16	29	21	110	33	11	17	4	11	6	13	11	1	11	27	3	44	20	9	11	1	...	..	+ 3
20	1	1	...	7	3	9	21	5	89	44	9	7	3	7	7	12	14	1	4	20	...	43	29	28	3	3	...	...	− 8
21	1	...	...	1	1	5	8	4	37	26	10	6	1	13	8	15	31	4	7	30	1	51	39	32	4	...	...	...	18
22	...	...	...	...	...	2	5	1	24	26	8	5	1	12	8	20	18	1	17	19	...	66	25	12	4	3	1	...	26
23	...	...	...	...	1	1	8	4	18	17	5	2	1	11	16	18	18	5	14	20	1	57	24	11	4	2	...	...	− 32
	5	4	5	28	34	89	199	106	741	484	180	165	38	264	169	460	384	68	351	774	35	1178	399	233	118	27	3	4	

Magnitude of Proper Motions.

The numbers of stars with proper motions between certain limits are given for each spectral type in Table II.

TABLE II.

The Numbers of Stars with Proper Motions between Certain Limits for Different Spectral Types.

	0″–1″.	1″–2″.	2″–3″.	3″–4″.	4″–5″.	5″–6″.	6″–7″.	7″–8″.	8″–9″.	9″–10″.	10″–15″.	15″–20″.	20″–
Bo–5	13	26	16	7	5	3							
8–9	61	73	79	38	22	6	5				1	1	
Ao	83	184	193	142	65	41	16	6	3	2	1	1	1
2	55	119	122	88	55	25	9	5	5	1	3	3	
3	13	32	40	33	24	14	7	7	1	2	2	1	
5	11	32	31	25	25	22	8	3	1	2	5		
Fo	25	38	59	33	30	25	17	10	6	8	7	3	5
2	11	28	13	28	23	18	14	6	7	2	15	4	2
5	16	46	70	77	51	42	29	30	15	12	43	12	11
8	14	37	41	43	55	34	39	25	20	12	44	8	9
Gc	18	28	41	49	21	18	29	21	13	15	37	21	34
5	37	86	118	98	76	68	35	31	26	20	70	42	51
Ko	96	183	245	179	128	97	58	40	15	23	54	15	41
2	27	83	92	78	50	26	11	11	4	1	7	3	6
5	24	50	53	37	21	18	8	4	4	1	7	1	4
M	13	26	31	28	13	17	9	5	1	2		1	1

This table shows very clearly how the proportion of stars of large proper motion increases to a sharp maximum for types Go and G5. This is indicated roughly but in a striking manner by comparison of the number of proper motions greater than 15″ a century with the number less than 5″ a century.

Type of Spectrum.	Number of Stars. p.m. $>15''$.	Number of Stars. p.m. $<5''$.	Proportion.
Bo–B5	0	67	1 : 250
B8–B9	1	273	
Ao	2	667	
A2	3	439	
A3	1	142	
A5	0	124	
Fo	8	185	1 : 23
F2	6	103	1 : 17
F5	23	260	1 : 11
F8	17	190	1 : 11
Go	55	157	1 : 2·8
G5	93	415	1 : 4·5
Ko	56	831	1 : 15
K2	9	330	1 : 37
K5	5	185	1 : 37
M	2	111	1 : 56

Among the types B, A, and M, the few stars with large proper motions are bright stars. The following list gives all the stars of these types with proper motion $>10''$ a century.

		m	$''$			m	$''$
B8	β Tauri	1·78	18	A2	40 Leo. Min.	5·55	12
B9	41 Arietis	3·68	13	A2	δ Herc.	3·16	16
Ao	α Andr.	2·15	21	A2	Lal. 42712	6·71	20
Ao	α Coron.	2·31	16	A3	P. III. 170	5·38	11
Ao	γ Coron.	3·93	10	A3	P. V. 256	5·81	18
A2	B.D. 24°, 550	9·1	10	A3	P. XII. 52	6·11	14
A2	*f* Leonis	5·73	11	Ma	β Pegasi	2·61	23
A2	*g* Leonis	5·33	19	Ma	α Vulpec.	4·63	17

The proper motion of B.D. 24°, 550 depends on a comparison with Berlin B, with a time interval of thirty-two years. As this is the only faint star of these types with large proper motion, it seems reasonable to suppose that accidental errors have accumulated and increased the true proper motion.

Solar Motion.

A determination of the solar motion was made for each type by Airy's method from equations of the form

$$X \sin \alpha - Y \cos \alpha = \mu_\alpha$$
$$X \cos \alpha \sin \delta + Y \sin \alpha \sin \delta - Z \cos \delta = \mu_\delta$$

where $X = M \cos A \cos D$

$Y = M \sin A \cos D$

$Z = M \sin D$

and M, A, D, are the parallactic motion, right ascension, and declination of the solar apex.

To simplify the arithmetical work, the stars were divided into hourly groups, and the mean position of each group taken to be at the even half-hours and at declination 28°.

The stars were divided into two groups according to magnitude —the division being made at $8^m{\cdot}0$. A few stars of very large proper motion were omitted. They are given in the following list:—

TABLE III.

List of Stars omitted on Account of Large Proper Motion.

Approx. R.A. 1910.	Approx. Dec. 1910.	Harvard. Mag.	Harvard. Spectral Type.	P.M. R.A. (unit ″·001).	P.M. Dec. (unit ″·001).	B.D. No.
h m	° ′					°
5 21	28 32	1·78	B8	+ 31	−177	28 795
6 58	29 29	5·95	F8	+158	−823	29 1441
7 48	30 53	8·2	Go	+725	−1848	31 1684
7 55	29 29	6·94	Go	−131	−1179	29 1664
13 8	28 20	4·32	Go	−797	+875	28 2193
16 0	25 29	7·06	Go	−527	+698	25 3020
23 57	26 36	5·85	Go	+834	−986	26 4734
17 43	27 46	3·48	G5	−322	−750	27 2888
15 55	27 59	8·1	Ko	−756	+304	28 2503
20 0	29 39	5·68	Ko	+670	−528	29 3872
23 40	29 3	8·9	Ko	+923	+ 18	28 4634
11 6	30 56	8·8	K5	+584	−212	31 2240
13 19	29 42	8·86	K5	−446	+239	29 2405
14 10	30 38	8·45	K5	−394	+158	30 2494
19 25	24 29	4·63	Ma	−127	−113	24 3759
22 59	27 36	2·61	Ma	+190	+133	27 4480

The results obtained for the solar motion are as follows:—

TABLE IV.

Determination of Solar Motion from Stars of Different Types of Spectrum and two Groups of Magnitude.

	$-7^m{\cdot}9$.					$8^m{\cdot}0-$				
Spectral Type.	No. of Stars.	Mag.	A.	D.	M.	No. of Stars.	Mag.	A.	D.	M.
		m	°	°	″		m	°	°	″
B8–9	158	6·88	274	36	1·60	131	8·34	304	27	0·94
A0	250	6·90	270	30	1·74	482	8·57	279	35	1·12
A2	148	6·90	274	35	2·46	334	8·71	286	34	1·10
A3	64	7·02	259	32	3·10	110	8·59	256	50	1·98
A5	62	6·91	267	21	3·69	103	8·66	280	46	1·37
F0	107	6 88	256	42	3·13	158	8·55	288	53	1·75
F2	59	7·16	263	28	4·04	108	8·56	292	42	2·28
F5	132	6·95	288	53	6·33	325	8·60	274	50	2·30
F8	59	7·29	269	49	5·93	322	8·65	272	43	3·44
G0	77	6·89	264	41	6·06	274	8·70	276	50	3·78
G5	177	7·20	279	39	5·87	597	8·70	279	54	3·65
K0	431	6·90	254	53	3·44	791	8·58	292	52	2·33
K2	132	7·24	262	56	2·39	260	8·50	305	60	1·61
K5	85	7·05	302	67	3·18	144	8·60	338	58	1·15
M	67	7·10	294	68	2·27	76	8·60	153	81	1·45

TABLE V.

Solar Motion for all Stars of Different Types of Spectrum.

Spectral Type.	No. of Stars.	Mag.	A.	D.	M.
		m	°	°	″
B–B5	76	6·89	273	37	1·34
B8–9	289	7·54	283	33	1·26
A0	732	8·00	275	34	1·38
A2	482	8·15	282	34	1·54
A3	174	8·00	257	41	2·34
A5	165	8·00	270	29	2·23
F0	265	7·88	270	46	2·23
F2	167	8·06	280	34	2·88
F5	457	8·13	281	54	3·62
F8	381	8·42	270	48	3·82
G0	351	8·52	270	49	4·39
G5	774	8·35	279	50	4·10
K0	1221	8·00	273	51	2·78
K2	392	8·08	293	59	1·80
K5	229	8·04	318	65	1·95
M	147	7·90	272	74	1·77

The increase of the declination of the apex from B to M is unmistakable. Comparison of the bright and faint stars serves to emphasise this, for though there are occasional large differences between them, they have no pronounced systematic character.

For the B and A stars the declination of the apex is approximately 35°; for the types F5 to K0, about 50°; while for the types K2 to M it reaches 65°.

A simple explanation of this may be that there is an increasing proportion of stars belonging to the second stream among the K and M types. The effect may be to some extent accentuated by the fact that the zone passes the anti-apex of Stream I. at 18h. At any rate, there are about here a large number of stars which from their large negative proper motion in declination may be assumed to be of Stream II.

In view of the very high declination of the apex given by the M stars, and that their numbers are not very great, their proper motions are given in detail. They may be compared with the B stars given in *M.N.*, **78**, 653.

List of M Stars.

Approx.		Proper Motion.		Harvard Magnitude.	Harvard Spectral Type.	Approx.		Proper Motion.		Harvard Magnitude.	Harvard Spectral Type.
R.A. 1910·0.	Dec. 1910·0.	R.A. (unit ″·001).	Dec. (unit ″·001).			R.A. 1910·0.	Dec. 1910·0.	R.A. (unit ″·001).	Dec. (unit ″·001).		
h m	° ′					h m	° ′				
5	24 42	−29	+10	8·2	Ma	2 12	28 35	+16	−18	6·85	Ma
5	28 9	−33	+ 1	8·1	Mb	33	27 7	+ 4	− 2	8·1	Mb
6	31 45	+21	+15	8·2	Ma	35	30 49	− 3	+18	Var.	Mc
16	24 50	+33	+ 8	7·86	Ma	50	30 40	− 4	−19	7·24	Ma
17	26 30	+44	+43	Var.	Md	3 16	31 55	− 7	−10	7·7	Ma
22	30 41	+ 5	+25	7·61	Ma	41	25 21	−24	−51	9·2	Ma
47	31 53	+ 7	−23	8·2	Ma	42	27 23	+16	−52	8·7	Ma
50	24 4	+20	−25	6·36	Mb	43	26 1	−45	+23	8·7	Ma
51	25 51	+36	− 4	8·2	Ma	59	25 57	0	+26	8·5	Ma
52	31 25	+20	− 9	8·1	Ma	4 18	28 48	+26	+13	8·0	Ma
54	24 33	−27	− 3	8·8	Ma	5 5	29 48	−11	−18	6·72	Ma
6	30 28	−13	−33	8·5	Ma	34	31 52	− 5	− 1	6·72	Ma
7	28 26	−45	−12	8·7	Ma	45	27 40	+13	−11	7·7	Ma
8	26 39	+27	−31	8·7	Ma	6 0	29 31	− 8	−26	6·32	Ma
9	28 3	+34	−59	6·63	Ma	3	25 40	+25	−39	7·6	Ma
12	25 49	− 7	−12	9·3	Ma	35	25 24	+41	− 4	8·0	Ma
17	31 22	+19	− 7	7·7	Mb	36	25 33	− 3	−46	7·8	Ma
40	28 17	+31	−41	7·9	Mb	40	26 53	−36	−49	9·0	Ma
52	27 22	+17	−53	6·02	Mb	55	27 29	+ 7	− 7	9·4	Ma
52	30 42	−41	−63	7·21	Mb	59	31 32	+45	− 8	6·80	Ma
3	24 23	+ 5	+16	7·7	Ma	7 0	28 8	+48	−19	9·1	Ma
10	24 38	+61	−13	Var.	Md	1	24 18	−10	−54	6·90	Ma

List of M Stars—continued.

Approx. R.A. 1910·0.	Approx. Dec. 1910·0.	Proper Motion. R.A. (unit ″·001).	Proper Motion. Dec. (unit ″·001).	Harvard Magnitude.	Harvard Spectral Type.
h m	° ′				
7 5	24 48	−24	−26	8·21	Ma
10	28 3	−19	− 9	5·87	Ma
14	31 32	− 5	−12	8·2	Mb
20	26 8	+23	+12	8·6	Ma
29	24 28	−16	−15	7·91	Ma
58	24 46	0	−17	8·16	Ma
8 2	30 47	− 7	−10	9·2	Mb
9	25 0	−16	−27	8·86	Mc
47	28 36	−16	−15	6·31	Ma
55	24 51	+21	−32	8·51	Ma
58	29 38	−28	−44	7·86	Ma
9 5	31 20	− 7	−37	Var.	Ma
25	25 27	+24	−21	8·7	Ma
31	31 34	+13	−42	5·74	Ma
45	31 49	+ 5	0	7·28	Ma
10 11	30 8	−13	−18	8·9	Ma
12	31 20	+19	+ 1	7·88	Ma
17	25 57	+ 5	−17	9·0	Ma
48	26 41	−33	− 7	7·28	Ma
58	30 25	−12	+13	9·2	Ma
11 0	31 5	−32	−29	8·8	Ma
26	28 57	−91	+ 3	7·00	Ma
58	30 10	− 7	−29	7·66	Mb
12 12	28 14	+32	+ 1	8·4	Ma
29	24 57	−16	− 8	7·45	Ma
40	24 5	−37	− 6	8·2	Ma
41	27 37	+25	−17	9·6	Ma
49	28 56	+91	−19	9·3	Ma
58	24 19	−67	−31	7·21	Ma
13 32	25 4	−12	−13	5·90	Ma
14 0	29 34	+ 9	−47	8·2	Ma
18	29 46	−42	−33	6·56	Mb
19	27 41	−20	−14	8·2	Ma
20	26 6	+35	−51	7·93	Ma
24	26 15	+36	−22	7·01	Ma
33	27 7	0	+33	Var.	Ma
39	26 54	−11	−21	4·93	Ma
14 57	31 44	−64	−52	8·2	Ma
15 17	31 41	+ 3	−27	Var	Ma
34	24 49	− 5	−36	7·12	Mb
52	31 29	− 9	− 6	8·1	Ma
16 2	31 9	+64	−11	8·3	Ma
7	29 22	+22	−46	9·1	Ma
21	29 27	−28	−29	9·2	Mb
34	27 13	−27	−46	7·08	Ma
39	26 13	+49	−49	8·1	Ma
44	31 45	+ 4	−37	8·7	Ma
51	29 11	+38	−44	9·1	Ma
56	27 27	−28	−10	7·26	Mb
56	26 23	+ 8	− 1	8·3	Ma
17 1	28 48	+23	−59	8·2	Ma
2	24 5	+ 5	−14	8·1	Ma
6	29 17	− 1	−16	8·3	Ma
14	29 1	−12	−13	7·07	Ma
15	27 23	−19	−16	7·06	Ma
30	29 49	0	− 9	7·71	Ma
32	27 37	+12	−69	6·57	Ma
36	31 15	− 4	+12	6·30	Ma
39	29 42	+44	−57	7·41	Mb
44	28 47	+53	−29	8·3	Mb
44	30 23	− 9	−23	7·91	Ma
47	30 7	+13	−26	8·16	Ma
49	30 46	−49	− 9	8·5	Mb
18 5	31 0	−12	+ 6	Var.	Md
6	24 47	−36	−49	8·6	Ma
8	31 23	− 8	+16	5·02	Ma
24	31 9	−17	−26	7·7	Mb
27	25 6	+15	−21	7·96	Ma
35	30 22	+17	−11	7·31	Ma
39	29 43	+17	−17	8·8	Ma
19 1	30 36	+33	−16	6·59	Ma
3	28 26	+36	+22	9·2	Ma
11	30 22	+26	−44	6·13	Ma
13	30 59	+ 7	+ 2	8·0	Ma

List of M Stars—continued.

Approx. R.A. 1910·0.	Approx. Dec. 1910·0.	Proper Motion. R.A. (unit ″·001).	Proper Motion. Dec.	Harvard Magnitude.	Harvard Spectral Type.
h m	° ′				
19 24	24 29	−127	−113	4·63	Ma
27	27 24	+11	− 5	9·1	Ma
27	27 34	+43	+39	9·2	Ma
28	31 40	+ 1	− 3	8·2	Mb
30	25 9	+32	−22	7·21	Ma
35	29 43	−23	−12	8·6	Ma
42	30 2	− 9	+ 5	7·76	Ma
54	31 14	+ 3	− 3	8·5	Ma
20 9	24 58	+39	+ 3	8·5	Mb
15	26 43	+11	−26	6·74	Ma
27	29 25	−23	−38	8·4	Ma
39	26 56	0	+ 3	7·8	Mb
44	27 55	−11	+ 5	7·9	Mb
59	24 6	− 1	− 5	7·74	Ma
21 24	24 15	+37	+ 8	9·4	Ma
32	31 42	+29	+19	7·8	Ma
21 35	30 22	+35	+ 2	8·71	Ma
45	29 16	+ 7	− 4	9·3	Ma
22 1	29 28	−66	−24	7·7	Ma
6	31 51	+20	−10	7·33	Mb
16	26 29	+ 3	+21	6·50	Ma
19	30 48	+ 4	− 3	7·46	Mb
36	26 16	+24	− 8	8·1	Ma
38	27 41	+57	− 1	8·8	Mc
39	29 8	− 7	− 2	8·8	Ma
44	26 52	+ 3	−16	9·1	Mb
59	27 36	+190	+133	2·61	Ma
23 31	24 4	−13	+36	6·64	Ma
42	27 55	0	−26	7·45	Ma
42	25 38	−13	+ 8	8·21	Mb
52	31 50	−17	+ 3	8·8	Ma
53	24 38	−42	−37	4·75	Mb

This paper may be compared with Boss's discussion in *A.J.*, 623–624. There he dealt with bright stars distributed over the whole sky, and with exceptionally well-determined proper motions. The fainter stars dealt with here show some clear differences. As regards the distribution, the proportion of F, G, K, and M stars outside the Galaxy is much greater. Boss finds that the declination of the solar apex from the F, G, and K stars is greater than from those of types B and A, though the difference is not so large as that found here. The M stars do not show the high declination obtained from the stars in this zone (24°–32° N. dec.). The following are the results given by Boss:—

Spectral Type.	A.	D.	M.	No. of Stars.
	°	°	″	
Oe5 to B5	274	35	2·73	490
B8 to A4	270	28	4·08	1647
A5 to F8	266	29	4·99	656
G	259	42	3·12	444
K	275	40	4·03	1227
M	274	39	3·29	222

Occultations of Stars by the Moon and Phenomena of Jupiter's Satellites observed at the Royal Observatory, Greenwich, in the year 1918.

(*Communicated by the Astronomer Royal.*)

Date and G.M.T. of Observation.	Star and Phase of Occultation.	Magnitude of Stars.	Observer	Aperture.
d h m s		m		inches.
Feb. 15 6 21 30·09[a]	101 Piscium, D	6·2	H.	10
6 37 8·72	,, R*	,,	H.	10
16 6 25 5·19[ab]	Bradley, 355, D	6·8	A.C.	$2\frac{3}{4}$
Mar. 20 6 30 34·54	ζ Geminorum, D	3·7	H.	10
6 30 34·66	,, D	,,	A.C.	$2\frac{3}{4}$
7 45 11·51	,, R*	,,	H.	10
21 9 42 8·72	3 Cancri, D	5·7	H.	10
9 42 9·75	,, D	,,	A.C.	$2\frac{3}{4}$
10 56 43·67	,, R*	,,	H.	10
23 7 0 48·66	*h* Leonis, D	5·2	H.	10
7 0 48·61	,, D	,,	A.C	$2\frac{3}{4}$
25 9 10 8·53[b]	p^3 Leonis, D	6·1	A.C.	$2\frac{3}{4}$
Dec. 10 8 5 2·98	Lalande 44904, D	6·4	W.	10
Oct. 22 10 49 56	Jupiter I. Occn. Re.	First seen	H.	10
10 52 6	,, ,,	Estimated bisection	H.	10
10 54 36	,, ,,	External contact	H.	10

The telescopes used are the 10-inch guiding telescope of the astrographic equatorial, and a portable telescope, aperture $2\frac{3}{4}$ inches, in the altazimuth dome.

The asterisk indicates that the phenomenon occurred at the Moon's Bright Limb.

Notes.

a. Dark Limb visible.

b. Star faint.

The initials H., A.C., W. are those of Mr. Hollis, Mr. Crommelin, and Mr. Witchell.

Royal Observatory, Greenwich:
1919 *Jan.* 8.

Micrometrical Measures of Double Stars (*13th Series*) *and New Double Stars.* By Rev. T. E. Espin.

In the following list the measures have been made with the 24-in. Calver reflector :—

Name.	R.A. 1900. h m	Decl. ° ′	P. °	D. ″	Mags.	Nts.	Date. 1918.
Espin 44	0 51·1	+56 57	249·7	8·58	7·5 11·8	2	·978
A.G.	1 49·1	60 6	262·2	8·91	9·1 9·3	2	·976
J. 6	2 23·1	58 58	134·0	2·96	9·2 10·5	1	·882
Σ 490	4 1·9	59 53	55·6	4·79	9·0 9·1	3	·991
Espin 62	5 17·3	41 2	61·6	3·29	9·5 12·0	1	·156
Espin 65	6 19·0	41 39	85·4	2·44	9·2 9·6	2	·204
Σ 1139 rej.	7 42·7	37 22	10·8	16·06	9·1 9·5	2	·204
Espin 179	50·3	37 59	87·8	3·91	9·5 9·6	2	·216
Σ 1204	8 9·3	38 47	101·1	11·30	8·6 9·1	2	·204
Σ 1239	26·0	37 50	287·6	12·07	8·8 9·2	2	·216
Σ 1274	42·6	38 43	40·2	9·03	7·6 8·9	3	·292
Espin 295	42·8	35 21	307·5	3·37	9·6 11·7	3	·270
Espin 294	42·8	36 31	161·8	1·75	9·5 9·7	2	·312
Σ 1282	44·5	35 26	274·6	3·62	7·0 7·1	3	·236
Σ 1321	9 7·7	53 7	69·1	19·09	7·6 7·8	2	·335
Σ 1338	14·7	38 37	179·5	1·50	7·0 7·2	5	·178
A.G. 164	17·6	38 51	20·2	4·55	9·2 9·3	2	·193
h 2509	46·8	37 41	66·9	14·33	9·6 10·4	2	·193
h 3318	56·7	36 44	341·8	24·05	9·5 10·0	2	·335
Espin 180	10 2·7	36 4	355·3	6·94	9·1 10·8	2	·335
h 2525	12·6	37 0	74·6	16·01	10·2 10·4	2	·335
Hu. 882	36·8	37 36	277·6	2·76	9·1 13·0	2	·193
Espin 181	11 7·7	36 16	139·8	6·00	9·2 10·4	3	·323
h 496	16·2	37 19	329·1	28·85	9·1 9·6	2	·335
h 502	28·3	37 35	270·0	1·2	9·5 12·0	2	·376 AB
			218·4	12·27	C=12·5	2	·376 AC
Espin 639	17 44·3	56 16	172·7	11·70	8·9 9·3	2	·750
Roé 17	50·0	59 40	53·5	9·17	8·5 9·2	3	·823
Espin 79	18 0·8	55 52	77·0	6·18	9·5 12·0	3	·759 AB
			94·0	25·21	C= 9·5	3	·759 AC
Espin 643	10·9	55 54	50·6	4·36	9·2 11·3	2	·750
Σ 2323	22·5	58 44	357·7	3·43	5·0 8·0	4	·637 AB
			254·5	36·05	C=14·0	4	·637 AC
			86·4	41·32	D=14·0	4	·637 AD
Espin 981	19 11·9	55 13	88·3	2·81	9·2 10·7	3	·865

Name.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
	h m	° ′	°	″			1918.
Espin 192	19 13·2	+59 35	113·8	5·91	8·8 10·2	3	·930
Espin 193	13·6	59 36	120·0	7·00	8·5 10·5	3	·930
Espin 132	20 7·6	56 39	80·4	5·58	8·8 9·0	2	·742 AB
			60·3	36·97	C= 8·7	2	·742 AC
A.G.	8·3	58 20	207·1	6·27	9·2 9·3	3	·903
h 2978	26·8	59 19	276·3	13·93	9·2 9·8	3	·947
Espin 92	39·3	48 54	121·7	9·13	8·0 8·2	3	·846
Espin 135	51·4	56 48	195·6	6·59	7·7 10·6	4	·966
Espin 136	57·2	56 51	161·1	4·29	9·2 9·4	3	·958
Σ 2780	21 9·2	59 35	225·4	1·10	6·1 7·0	4	·768
Σ 2790	16·5	58 12	48·5	5·12	6·5 9·0	2	·923
Holmes	17·3	58 17	65·0	13·64	9·2 9·4	2	·984
OΣ 440	24·7	59 19	181·8	11·22	6·5 9·6	2	·976
h 1748	22 13·1	58 2	276·2	7·65	9·5 9·6	2	·960
h 1782	28·8	59 37	315·9	4·46	11·0 11·2	3	·981
h 1783	28·9	59 43	272·4	6·37	9·8 9·9	2	·979
Espin 38	23 54·0	56 35	236·3	18·91	9·0 9·5	2	·999

Notes.

A.G., $1^h\ 49^m{\cdot}1$. Not in β's G.C.
J. 6. Milburn P. 136°·1, D. 2″·95, mags. 9·0, 11·2. 1918·882.
Espin 62. Also a 9·7 N.
Σ 1139 rej., Espin 179, *h* 2509, *h* 3318, *h* 2525. No other measures.
h 502. It is very doubtful whether the new companion is not a "ghost."
Σ 2323. The two faint stars were detected by Mr. Milburn with the 17¼-in.
Espin 192. Motion probable.
A.G., $20^h\ 8^m{\cdot}3$, Hels. Gotha. Cat. of the Astron. Gesell., Introduction, p. 7, Dupl. 8″, 9·5, 9·5. Not in β's G.C.
Espin 38. In *A.N.* 1717 and β's G.C. for 337° read 237°.

New Double Stars.

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
		h m	° ′	°	″			1918.
1706	+59° 2831	0 2·3	+59 35	79·1	2·00	9·5 10·3	2	·874
1707	+60° 44	18·3	+60 17	103·5	7·99	9·3 12·5	2	·847
1708		48·3	+60 8	303·1	3·70	9·6 12·0	2	·861
1709	+58° 137	50·5	+58 55	282·2	5·25	9·5 11·0	2	·940
1710	+58° 146	53·1	+59 11	332·7	6·04	8·5 9·0	2	·948
1711	+58° 145	53·2	+58 57	54·2	2·89	9·3 10·8	3	·943
1712	+58° 231	1 18·0	+58 26	297·0	5·66	8·9 13·5	2	·845
1713	+57° 282	19·7	+58 1	147·1	1·37	9·4 9·5	3	·854
1714	+59° 528	2 33·1	+60 0	81·8	3·37	9·5 13·2	2	·993
1715	+59° 753	3 59·1	+59 52	162·2	5·49	8·5 10·2	2	·986

New Double Stars—continued.

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.	
		h m	° ′	° .	″			1918.	
1716	−40° 1097	4 49·9	+40 39	137·3	5·64	9·2 11·2	3	·122	
1717	+40° 1132	54·0	+40 20	233·6	1·85	9·3 10·0	2	·180	
1718	−40° 1144	55·5	+40 5	272·5	2·09	9·5 9·7	2	·204	
1719	−40° 1159	57·4	+40 23	22·7	4·64	9·5 12·0	2	·189	
1720	+41° 1071	5 1·4	+41 57	117·1	3·47	9·3 9·7	2	·130	
1721	+40° 1189	3·3	+40 32	162·1	5·66	8·4 11·2	2	·204	
1722	+41° 1105	5·0	+41 46	302·1	5·10	8·5 12·0	3	·168	
1723	+41° 1130	9·0	+41 47	210·7	2·37	9·2 9·3	3	·168	
1724	−41° 1194	21·0	+41 5	228·6	2·59	9·5 11·7	3	·168	
1725		26·8	+40 40	214·4	2·56	10·5 10·8	1	·222	
1726	+40° 1412	40·4	+40 15	75·9	2·89	9·3 9·4	2	·250	
1727	+41° 1280	42·9	+41 4	51·4	2·49	9·4 9·5	2	·163	
1728	+41° 1298	47·5	+41 2	264·0	5·43	9·1 9·2	2	·189	
1729	+40° 1484	56·1	+41 0	313·0	6·83	8·9 10·7	2	·204	
1730	+41° 1390	6 6·1	+41 25	140±	4±	9·5 14	1	·161	
1731	+39° 1989	7 35·6	+39 50	98·5	1·28	9·2 9·3	4	·158	
1732	+38° 1907	8 17·7	+37 56	67·0	8·01	8·5 9·2	2	·247	
1733		54·3	+38 46	323·2	2·83	9·5 10·7	3	·207	
1734		9 11·4	+37 6	67·3	2·62	10·2 10·7	2	·236	
1735		14·4	+37 34	181·0	4·11	10·1 10·6	2	·247	
1736	+38° 2071	43·4	+38 14	106·3	1·16	9·2 10·5	2	·220	
1737	+36° 2121	10 41·1	+36 10	279·4	1·75	9·5 9·6	2	·282	
1738	+38° 2276	11 40·8	+38 3	162·4	1·97	9·3 9·6	3	·323	
1739	+37° 2258	12 9·0	+37 28	291·7	4·51	9·4 12·0	3	·323	
	+56° 1904	16 33·6	+56 45	188·7	9·61	9·2 9·7	2	·666	
1740	+56° 1969	17 16·7	+56 14	314·7	1·61	9·5 12·0	4	·737	
	+56° 1977	20·2	+56 43	73·1	11·47	10·0 10·3	2	·742	BC
				92·1	29·94	A=7·5	2	·742	AB
	+57° 1765	25·3	+57 22	2·3	10·16	8·9 11·0	2	·653	
1741	+57° 1768	26·8	+57 7	181·1	2·56	9·3 9·5	2	·675	
1742	+57° 1772	28·5	+57 47	33·4	1·76	9·5 10·2	3	·649	
	+57° 1775	30·1	+56 59	210·5	13·85	8·0 9·2	4	·719	
1743		44·3	+59 16	73·8	2·04	10·5 10·7	2	·735	BC
				231·3	30·17	A=9·6	2	·735	AB
1744	+57° 1823	54·7	+57 32	264·9	6·89	9·2 9·4	2	·630	
1745	+56° 2058	18 1·0	+56 22	226·4	4·91	9·5 13·0	3	·692	
1746		51·4	+58 7	114·5	1·62	9·6 9·8	2	·691	
1747	+57° 1923	55·1	+57 15	163·5	1·62	9·2 9·4	3	·714	

New Double Stars—continued.

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
		h m	° ′	°	″			1918.
1748	+55° 2134	18 57·8	+55 35	57·1	6·35	8·7 10·0	2	·861
1749	+56° 2186	19 1·6	+56 5	179·5	6·14	9·4 9·8	2	·830
1750	+58° 1883	11·6	+58 24	313·6	4·88	9·5 13·5	3	·710
1751	+56° 2215	12·6	+56 14	351·1	6·74	8·8 14·0	3	·822
1752		13·5	+59 14	321·6	3·79	9·6 12·2	3	·805
1753	+56° 2219	14·0	+56 15	57·4	3·09	8·2 12·5	3	·822
1754	+57° 1994	19·7	+57 19	85·7	5·68	9·3 13·5	3	·754
	+55° 2265	46·3	+55 45	257·1	9·04	8·5 9·6	2	·855
1755	+59° 2151	54·9	+59 43	173·5	5·39	8·5 9·2	2	·871
1756	+56° 2339 ?	58·2	+56 12	180·9	2·29	9·5 9·6	2	·845
1757	+58° 2039	20 1·2	+59 4	213·3	2·62	9·6 10·8	4	·899
1758	+58° 2062	7·9	+58 38	174·2	5·23	9·5 10·7	2	·890
1759		27·2	+59 12	220·1	2·43	10·0 10·2	3	·902 AB
				303·0	5·45	C=10·3	2	·880 AC
	+58° 2209	58·4	+59 7	52·2	10·09	9·2 9·2	2	·695
1760	+56° 2537	21 7·8	+56 46	39·9	2·56	9·0 12·5	3	·868
	+58° 2259	20·7	+58 56	265·1	12·81	9·3 10·5	3	·967
1761	+58° 2321	41·8	+59 9	340·4	3·56	9·4 9·8	3	·924
1762	+57° 2513	22 18·5	+58 13	341·4	6·35	9·2 13·7	2	·997
1763		33·6	+59 44	213·2	2·42	10·7 11·1	3	·981
1764		36·6	+59 49	255·5	3·87	9·5 12·7	3	·966
1765	+59° 2709	23 18·0	+59 19	232·2	2·02	9·2 10·2	2	·907
1766	+59° 2733	25·0	+59 35	319·2	3·37	9·5 9·6	2	·873
1767	+59° 2767	41·2	+59 40	36·0	5·55	9·5 11·6	2	·861
	+58° 2650	43·2	+59 14	84·2	8·81	9·0 10·2	2	·873
1768	+59° 2792	52·2	+60 5	0·2	6·89	9·2 10·8	2	·855

Notes.

1712. An 8·0 mag. at 185°·0, D. 49″·11, orange, B.D. +58°·230. B.D. +58°·231 is much underrated in Argelander.
1716. Also a 10·5 mag. at P. 341°·4.
1720. A 14 mag. at P. 140°·4, D. 15″±.
1734. s.p. Σ 1334.
1745. This star is given in the B.D. as 9·1 mag. ; it is certainly less.
1749. Also an 11·5 mag. at 257°·3, D. 17″·5 from B.
1756. The R.A. agrees with the B.D., but this star is some 2′ north of Argelander's place. There is no star above 12·5 mag. in his place, and no star on the Harvard Map of the sky.
1758. A 9·7 mag. at 357°·8.

The following have been found by Mr. Milburn with the 17¼-inch, and have been measured with the 24-inch :—

No.	B.D.	R.A. 1900. h m	Decl. ° ′	P. °	D. ″	Mags.		Nts.	Date. 1918.	
36	+58° 1	0 3·0	+58 40	359·1	6·58	8·7	11·2	2	·960	
37	+56° 5	3·3	+56 28	199·1	2·96	9·4	11·7	2	·994	
38	+58° 42	19·1	+59 13	79·6	5·14	10·0	12·0	3	·854	
39	+57° 90	23·6	+57 19	198·6	3·49	9·4	9·6	3	·985	
40	+56° 93	31·1	+57 3	334·9	2·81	9·5	9·6	2	·999	
41	+59° 115	41·2	+59 48	151·1	7·22	9·5	9·6	3	·861	
42	+58° 128	47·0	+59 7	223·4	2·45	9·2	9·5	3	·847	
43	+59° 171	57·0	+60 0	298·0	7·98	9·4	9·4	2	·861	
44	+58° 275	1 35·2	+58 54	139·3	3·60	9·5	9·7	2	·907	
45	+57° 393	41·4	+57 52	122·7	2·41	9·6	9·8	3	·864	
46	+57° 397	41·8	+57 23	335·9	2·56	9·5	9·6	2	·861	
47	+58° 311	44·0	+59 9	173·7	2·41	9·4	11·7	3	·971	AB
				306·7	5·96	10·0	13·6	3	·985	CD
				130·5	36·89				·979	AC
48	+58° 333	49·6	+58 31	69·7	1·51	9·5	9·7	4	·923	
49	+59° 418	2 3·0	+59 51	1·1	5·40	9·5	11·5	2	·855	
50	+55° 662	29·2	+55 51	29·3	5·96	9·5	11·3	2	·968	
51	+57° 609	33·4	+57 16	178·7	5·20	9·6	12·0	3	·956	
52		35·5	+57 48	4·2	4·50	10·0	10·3	2	·900	
53	+58° 548	54·1	+58 27	103·4	6·18	9·2	10·1	3	·921	
54	+56° 821	3 26·1	+56 55	16·9	4·31	9·3	9·6	4	·987	
55		27·3	+40 28	34·3	4 20	9·4	10·7	2	·830	1917
56	+59° 696	33·5	+59 32	311·1	6·08	9·5	13·2	2	·999	
57	+59° 757	4 0·0	+59 36	225·4	2·52	9·5	11·2	2	·968	
58		2·5	+55 29	351·0	3·78	9·5	9·7	2	·999	
59	+57° 837	36·6	+57 6	330·2	7·10	9·2	9·4	2	·968	
60		56·0	+40 52	148·8	3·97	11·7	11·9	3	·177	
61	+56° 1026	5 17·6	+57 2	57·2	2·91	9·6	10·5	1	·975	
	+41° 1354	59·9	+41 46	238·5	9·58	8·3	9·6	2	·149	
62		6 21·4	+40 22	179·7	6·02	10·1	10·6	3	·243	
63		32·0	+42 25	260·0	5·33	9·2	9 8	3	·230	
	+41° 1559	50·8	+41 37	178·8	10·98	9·4	10·0	3	·177	
	+39° 1886	7 5·4	+39 46	78·2	10·78	8·6	11·2	2	·216	
64		40·3	+38 48	5·6	4·06	9·5	10·4	2	·187	
65		9 19·2	+38 42	316·8	4·20	11·1	11·2	3	·190	
66	+36° 2116	10 40·0	+36 29	181·1	4·45	9·5	10·2	4	·242	
67	+57° 1371	12 18·3	+56 56	145·9	7·43	9·5	10·6	2	·416	
68	+37° 2286	25·8	+37 13	170·2	4·73	9·5	9·6	3	·323	
69	+58° 1435	13 13·4	+58 43	43·0	3·89	9·4	9·9	3	·421	
70	+58° 1447	23·2	+58 38	237·6	5·30	9·3	12·0	3	·421	
71	+58° 1580	15 34·8	+58 44	283·9	3·48	9·3	9·9	3	·421	

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
		h m	° ′	°	″			1918.
72	+60° 1625	15 35·2	+60 41	2·6	1·77	9·5 9·6	6	·576
	+59° 1699	16 2·4	+59 39	214·0	10·93	8·5 9·9	2	·416
73	+58° 1623	8·8	+58 53	183·9	1·88	9·4 9·5	4	·517
74	+57° 1688	32·6	+57 48	271·0	5·45	9·4 12·0	2	·517
	+57° 1806	17 46·3	+57 9	181·8	11·28	8·6 10·5	2	·687 AB
				48·6	18·24	C=13·5	2	·687 AC
75	+57° 1818	51·4	+57 14	326·1	2·73	9·5 10·5	4	·612
	+59° 1920	18 44·5	+59 17	278·9	8·83	10·6 11·5	2	·664 BC
				202·7	35·76	A=9·3	3	·671 AB
76	+58° 1836	47·8	+58 4	140·9	5·22	9·6 10·5	2	·653
77	+59° 1954	19 7·4	+59 44	180·5	6·39	9·4 9·5	2	·653
78	+58° 1875	8·8	+58 44	54·2	5·16	9·5 9·8	2	·653
79		27·4	+58 59	317·1	4·00	10·0 10·5	2	·675
80	+56° 2258	30·9	+56 47	180·3	6·45	9·5 10·2	2	·758
81	+59° 2077	34·7	+59 42	176·2	6·45	9·5 10·3	2	·653
82		59·3	+58 52	11·0	5·12	11·2 11·7	2	·691
83		20 6·6	+57 51	90·3	6·03	10·5 11·0	3	·689
84	+56° 2414	22·8	+57 7	152·0	7·90	9·0 13·5	3	·834
85		37·5	+58 23	133·9	6·25	9·9 11·8	2	·691
86	+56° 2493	46·9	+57 5	143·7	6·77	9·5 9·7	2	·682
	+58° 2220	21 1·9	+58 40	29·8	9·76	8·7 11·8	3	·695
	+59° 2354	16·2	+59 13	105·3	10·06	8·4 9·8	2	·795
87		17·2	+57 13	330·4	2·61	10·0 10·1	3	·852
88	+59° 2375	23·1	+59 31	114·3	7·22	9·2 10·5	2	·722
89	+59° 2394	28·1	+59 49	58·0	5·83	9·4 9·5	2	·760
90	+57° 2360	36·7	+57 48	41·3	8·22	8·5 10·2	2	·694
91	+57° 2378	40·3	+58 7	72·0	4·45	9·4 9·5	3	·832
92		54·3	+59 8	53·9	5·39	10·7 11·0	2	·760
93	+57° 2439	57·4	+58 3	305·3	4·24	9·5 9·8	2	·844
94	+56° 2695	22 1·2	+56 20	305·9	6·00	9·1 10·8	2	·873
95	+56° 2749	13·2	+56 41	251·7	2·33	9·4 11·7	4	·768
96	+55° 2761	27·1	+55 59	51·9	2·46	9·4 10·3	3	·845 AB
				191·6	14·51	C=12·0	3	·845 AC
97	+60° 2417	32·4	+60 22	64·6	7·06	9·5 11·0	2	·848
98	+58° 2498	48·8	+58 55	267·5	3·56	9·6 10·2	3	·924
99	+57° 2655	54·2	+57 59	279·3	3·02	9·2 9·4	2	·845
100	+56° 2918	54·7	+57 5	317·8	2·95	9·5 9·6	2	·861
101	+59° 2638	23 0·3	+59 50	293·7	7·56	9·5 10·7	3	·869
102		1·3	+57 27	162·4	6·00	9·2 11·5	3	·943
103	+55° 2995	34·1	+56 6	336·9	4·91	9·5 9·6	1	·843
104	+56° 3090	42·5	+56 48	353·6	5·96	9·3 11·5	2	·845
105	+55° 3065	54·2	+55 58	227·1	3·19	9·4 11·7	2	·994
106		57·5	+59 9	49·6	2·93	10·5 11·7	3	·973

Notes.

40. Milburn, another star, 9·5 mag. at P. 328°, D. 81″.
44. At P. 334°·8 from B.D. +57°·616.
60. At P. 207° from B.D. +40°·1149.
61. Milburn, P. 58°·9, D 2″·83. 1919·003.
68. ,, P. 169°·9, D. 4″·83, mags. 9·5, 9·6. 1918·356.
70. ,, P. 237°·1, D. 5″·41. 1918·363.
72. This star has a considerable proper motion in declination, as is shown by comparisons with the neighbouring star B.D. +60°·1619, and Mr. Franks has kindly made measures of the present difference. It is A.Ö. 15538, and we have the following:—

Difference in declination	1842·38	81″·6 A.Ö.
	1873·36	96·0 A.G.
	1918·54	106·17 Franks.

The later results yield a P.M. +0″·23.

79. Milburn, P. 316°·8, D. 4″·12. 1918·665.
83. At P. 197°·8 from B.D. +57°·2147.
90. Also a 9·8 mag. at P. 138°·4.
103. Milburn, P. 353°·1, D. 5″·85. 1918·760.
104. *Comes*, 13·5 mag., P. 178°·8, D. 9″·79. 1918·846. I *nt.*

B.D. Stars found to be Faint or Missing.

		h m s		° ′	
(1)	+59° 170	0 54 7·1	(1855)	+59 5·1	mag. 9·0
(2)	+40° 1269	5 12 55·1		+40 39·8	9·5
(3)	+41° 1198	18 58·5		+41 26·4	9·5
(4)	+41° 1297	44 15·5		+41 8·9	9·5
(5)	+40° 1821	7 6 30·6		+40 29·7	9·5
(6)	+39° 1963	22 54·8		+39 59·7	9·5
(7)	+56° 2292	19 40 42·0		+56 43·6	9·2
(8)	+57° 2236	20 39 15·2		+57 50·6	9·5
(9)	+57° 2437	21 53 54·4		+57 42 5	9·5
(10)	+58° 2557	23 5 3 0		+58 29·6	9·5

Notes.

(1) Not seen in moonlight, 1918 Nov. 19. Mag. 9·8, *nf* of 2, Dec. 13. 11 mag. in Harvard Map of the sky. A.G. 9·6.
(2) 11·5 mag., 1918 March 22. Faint in H.M. of the sky; and Barnard's photo.
(3) No star here, 1918 Feb. 8; there is a 9·5 mag. 5′ ± N.
(4) Not seen, haze, 1918 March 9; faint wide pair, March 13.
(5) No star seen, 1918 Feb. 8; a star 9·5 mag. $1^m\pm$ preceding.
(6) No star seen by Milburn, 17¼ in.; no star, 24 in., 1918 March 13. A star 5′ ± S.
(7) Not seen by Milburn, 1918 Sept. 26. Not in H.M. of the sky.
(8) Faint, Milburn. 1918 Aug. 31, 12·0 mag. Not certainly seen in H.M. of the sky.
(9) 11 mag., 1918 Dec. 29. Faint on Barnard's photo. Not seen in H.M. of the sky.
(10) 11 mag., 1918 Dec. 24. On Barnard's photo No. 85, bright; No. 86, faint. Seen on H.M. of the sky. Variable?

Observation of a Bright Projection on the Limb of Jupiter.

By F. Sargent.

A phenomenon of great rarity, if not quite unique, was observed by me at Bristol on the evenings of 1919 January 16 and 17.

On directing the telescope to the planet Jupiter at $8^h\ 50^m$, it was at once seen that the contour of the "following" limb was broken by a projection of great brilliancy, as though being seen in profile. Its position was on the Equatorial Zone, and about midway between the North Equatorial Belt and the Equator. The projection was seen to subside slowly, leaving the limb unbroken at about $9^h\ 20^m$, when the object was seen as a bright spot on the tinted Equatorial Zone. The spot was clearly visible until clouds put an end to observation for the remainder of the evening.

On the following evening Jupiter came under observation at $6^h\ 5^m$, when the bright spot was found about midway between the "following" limb and the central meridian. It was situated in a bay on the south edge of the North Equatorial Belt. As it approached the central meridian its brilliancy lessened, the spot ultimately becoming invisible, its position being known only by means of the bay in which it was situated. This bay was timed to transit the central meridian at $6^h\ 46^m{\cdot}5$ (Long. 266° 6, System I.).

At $7^h\ 10^m$ the spot again became visible, and was followed right up to the limb, meanwhile growing in brilliancy. At $8^h\ 53^m$ projection from the limb was suspected. At 9^h the object was "flickering" in and out of the limb. At $9^h\ 10^m$ it was steadily observed to break the usually even contour of the limb, and then, slowly subsiding, was judged to have disappeared at $9^h\ 20^m$. It was not possible to re-observe the object on the 18th, on account of unfavourable weather.

By way of explanation, we have a choice of alternatives: a real material projection from the surface of the planet, of dimensions great enough for it to be visible; or, irradiation due to excessive brilliancy of a spot at or near the normal level of its surroundings, similar to the familiar phenomena presented by the brilliant polar caps on Mars.

I am of opinion that the former suggestion best accords with the facts of observation, as on the second suggestion it is difficult to explain why an object of such brilliancy should become invisible when approaching the central meridian. It is a fact of common observation that features excessively bright when on the central meridian are observationally lost when near the limbs, and the fact that this order is reversed with the object now seen, seems to indicate that intrinsic brilliancy is not the supreme factor.

Bristol:
1919 *Jan.* 20.